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THE APPLE MAGGOT

By W. C. O'KANE

NEW HAMPSHIRE COLLEGE
OF
AGRICULTURE AND THE MECHANIC ARTS
DURHAM, N. H.

NEW HAMPSHIRE AGRICULTURAL EXPERIMENT STATION.

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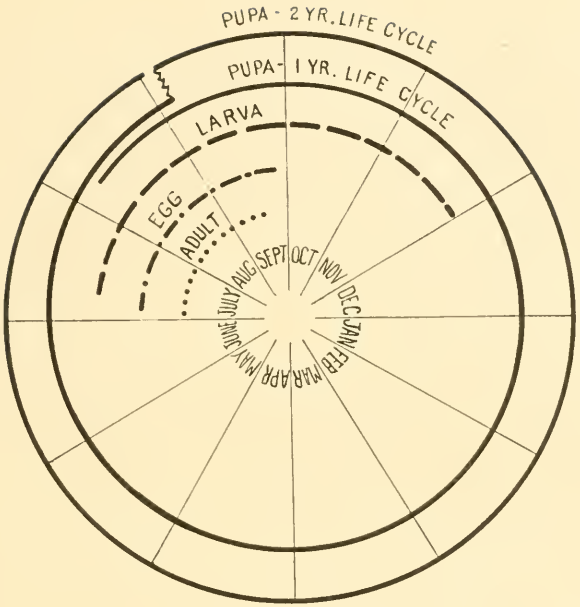

FIG. 1. LIFE CYCLE OF THE APPLE MAGGOT.

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THE APPLE MAGGOT.

W. C. O'Kane.

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INTRODUCTION.

The Apple Maggot, or railroad worm, *Rhagoletis pomonella* Walsh, is clearly one of the principal insect enemies of the apple in the northeastern fruit-growing region of America. Through much of this area orchardists are familiar with the brown tunnels made by the larvæ through the pulp of the fruit, especially in early varieties, and with the small white maggots responsible for the damage. Commonly the grower describes the situation with the statement that he cannot raise any early or sweet fruit that is fit to eat. Often the comment is added that sometimes his winter fruit is invaded, especially trees in certain locations with reference to the rest of the orchard.

An investigation of the species was begun by the New Hampshire Agricultural Experiment Station five years ago. The work was started with preliminary studies by Professor C. F. Jackson in the summer of 1909. It was made a major project of the Station in the fall of the same year under the direction of the writer, and has remained actively in hand throughout the succeeding four years.

Certain information secured, of a direct practical bearing, was made public in a circular sent to the New Hampshire mailing list in 1911 (41). Some facts of interest to entomologists were published in the *Journal of Economic Entomology* in the same year (42). The complete record of the investigation to date is presented in this bulletin.

Grateful acknowledgment is made of the zealous and painstaking work of the writer's assistants, Mr. C. H. Hadley, Jr., and Miss Cornelia F. Kephart. Most of the field studies of the last two years have been worked out by Mr. Hadley. The investigation has been favored, also, by consistent support on the part of Director J. C. Kendall, of this Station.

SYSTEMATIC POSITION AND COMMON NAME.

The apple maggot is a member of the family *Trypetidæ*, a large group of two-winged flies, the larvæ typically inhabiting living plant tissues. It was first assigned to the genus *Trypeta*. The original description was published in 1867 by Benjamin Dane Walsh (58), then acting state entomologist of Illinois, who had reared adults from haws collected in Illinois and from larvæ acquired from Long Island, Connecticut, and Massachusetts. To the new species he gave the name *Trypeta pomonella*.

In the course of some prior systematic work on the group by Dr. H. Loew the genus *Trypeta* had been subdivided. These subdivisions holding, the species *pomonella* fell within the genus *Rhagoletis*. The name as it now stands is *Rhagoletis pomonella* Walsh.

The common name, "apple maggot," was in use at the time Walsh published his description. The name "railroad worm" is current among many growers in New England. In New Hampshire this term is almost universal. Evidently this name is suggested by the tracks made by the maggot beneath the skin of the fruit of certain varieties. Growers frequently speak of infested apples or infested trees as "railroaded" or "railroady." In one section the common name of the species is "run-arounds."

EARLY HISTORY.

Unquestionably the apple maggot was injuring cultivated varieties of apple in various localities considerably more than half a century ago. When Walsh described the species in 1867 he noted, in addition to the record for Illinois, serious infestations existing in Massachusetts, Connecticut, central New York, and at a point on Long Island. Vermont was already on the list in an observation published in 1866 (60). It is probable that the maggot was at work in cultivated apples in these places and in others much earlier than the public writings specified.

As time went on, and as entomological records were extended, the published range of the species in cultivated fruit was increased. In part this was due, doubtless, to the gradually increasing damage done by the insect, in part probably to the augmented interest in insects and the further study of them by entomologists.

In 1872 Riley (52) identified an infestation called to his attention from Keene, N. H., with the observation, however, that the species existed in the east and west, feeding on wild haws, and was but now turning its attention to the cultivated fruit. Maine was added to the printed list in 1876 by Riley (53), who again identified an infestation complained of by a fruit-grower.

Thus in the first ten years of published accounts the species was of record in seven states, including Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York and Illinois.

In 1881 Professor Comstock (8) reared the adults from haws collected in Washington, D. C. The states of Michigan and Wisconsin were added in 1884 by Professor Cook (9), who wrote that the maggot had been known to infest thorn apples in Michigan, Wisconsin and Illinois for years, but had not been observed attacking the cultivated apple in Michigan before that year. New Jersey was added in 1889 by E. Williams (65). In 1891 Professor Osborn (43) recorded injury in Iowa and Professor Weed (62) in Ohio. The species was noted from North Carolina in 1894 by Dr. Howard (33). Observations on its work in Rhode Island were printed in 1896 by L. F. Kinney (38).

In 1896 the maggot was recorded in Ontario by Dr. Fletcher (16). This should not be quoted, however, as the first finding of the species in Canada, but as the first observation of it in cultivated fruit. Dr. Fletcher stated that the maggot occurred abundantly in haws in many localities, and that he had himself bred the fly in 1887, ten years before, from haws collected at London, Hamilton, Toronto, Montreal and Ottawa. In 1904 Dr. Fletcher (19) recorded infestation of cultivated fruit in Quebec, and in 1906 (21) in New Brunswick.

Beginning in 1882 an increasing number of articles concerning the species appeared in print, aside from the records noted above. For the most part these described notable damage wrought, or other similar matters.

INVESTIGATIONS ELSEWHERE.

The first serious investigation of the species was conducted in 1888 and 1889 by Professor Harvey (25), then entomologist of the Maine Station. The work of Professor Harvey was that of a pioneer, and many valuable facts were determined. The

most noteworthy achievement was the definite proof that the adult female lays its eggs beneath the skin of the fruit—a matter of great importance economically.

From 1896 to 1905 experiments were conducted at the Rhode Island Station by L. F. Kinney (38), Card and Adams (3, 4), Card and Stene (5), Card and Blake (6), and F. W. Card (7). Remedial measures, principally, were considered.

In 1912 the Cornell Station published the results of an extensive biologic study of the species by Dr. J. F. Illingworth (34), under the direction of Professor Herrick. These studies, which were in progress through 1911 and 1912, provided valuable information on many phases of the life economy of the maggot, together with admirable histologic data.

In 1913 William A. Ross of the Division of Entomology, Ottawa, made a preliminary report of an investigation in progress through 1912 and still under way (55). These studies were carried out in conjunction with Mr. Lawson Cæsar, provincial entomologist of Ontario.

SOURCE AND FOOD PLANTS.

It is probable that the apple maggot is a native American species, distributed originally in somewhat scattering fashion through certain areas in the northeastern part of this country, between the fortieth and forty-fifth parallels.

That the species may be an importation is possible. There is, however, no evidence available at this time to show that it has existed or now exists in any other country. Dr. H. Loew, who gave critical attention to the genus, did not find it in collections of European *Trypetidæ*. The nature of early records in this country does not favor a foreign origin.

If it is a native species, its original host plant is to be looked for, presumably, in at least some part of the region it now normally inhabits, and in wild fruit indigenous to that region. It may fairly be assumed, also, that the original host is some fruit that the maggot now infests, at least occasionally. It does not follow that the source is necessarily one of the wild fruits in which the maggot has actually been recorded, although the assumption is in favor of recorded hosts.

THE APPLE.

A present general food plant of the maggot is the cultivated apple in its many varieties and hybrids, including the wild apples or seedlings that are derived from the cultivated fruit and are found in large numbers in New England. This is the host in which the species reaches its present large economic importance and in which most individuals of the species now pass their larval life. A fuller discussion of the relative severity of attack in various varieties of apples will be found later.

Neither the cultivated apple nor the wild seedlings can have been the original host of the species in America. The former did not exist in this country prior to the coming of Europeans. It is not conceivable that the species came into existence since that time. The seedling apples are offshoots of the cultivated apple. While they are now plentiful in a wild state, both near to and remote from orchards, and frequently are infested, all of them bear the blood of the cultivated apple and therefore cannot have been the original food plant of the maggot.

THE PEAR.

Harvey, in his report for 1892 as entomologist of the Maine Experiment Station (26), states that he had learned through a Vermont correspondent that the apple maggot infests pears in that state. This was the only evidence available. The same report states that the species had not been observed in pears in Maine. So far as the writer is aware there is no verified published record of infestation of pears.

CRAB-APPLES.

The apple maggot was noted in crabs by Riley in 1872 (52). It was recorded again in this fruit by Fletcher in 1905 (20). In his preliminary report for 1912 Ross (55) states that he found the maggot at work in a crab-apple that was in close proximity to a badly infested orchard.

The writer has inquired of entomologists in all of the sections in which the apple maggot is found, and through their coöperation is able to offer the following additions to the record. Professor M. B. Cummings of the University of Vermont states that he has occasionally seen the species in crabs. Professor R. H

Pettit of the Michigan Agricultural College writes that he has many times found in crabs what appears to be the same larva, but that attempts to breed the adults have not been successful.

In New Hampshire the writer has observed maggots in crab-apples growing in an orchard at Durham in which there are trees badly infested with the apple maggot. The adults were not reared. Reports from growers in New Hampshire occasionally state that crabs are attacked, one orchardist adding the comment that of two trees, one a yellow variety and one a red, one was infested and the other was not. The writer believes that the species is apt to occur in crabs that are located immediately adjacent to badly infested early apples, under the same circumstances which, as described later, may bring about infestation of hard, winter apples, that are not naturally adapted to its life economy. Varieties of crabs that mature their fruit early and become mellow before freezing weather may serve as acceptable hosts in the absence of other fruit near by.

The New Hampshire notes as above cited refer to hybrid crabs; in other words the varieties commonly found in orchards or about farm homes. Whether the records cited from the writings of Riley and Fletcher refer to the same is not clear. Professor Pettit's observations refer to hybrid crabs. The notes from Vermont may not now definitely be assigned to either. The observations of Ross refer to the Siberian crab, *Malus baccata* Desf.

If the maggot had its original home in the fruit of crabs, it must have been in one of the native, American species. The common crabs of our farms and orchards are hybrids of the wild Siberian crab and the cultivated apple (1). None of them could have served as the source of the species, for the same reason that none of the cultivated apples could have done so.

Of the native wild crabs we have three species (1). Two of these, *Pyrus angustifolia* and *P. rivularis*, do not have such range as would make them probable original hosts. The former is our southern wild crab, found from Pennsylvania to Florida and west to Louisiana. The latter is the "Oregon crab" of the north Pacific coast. The third native species is *P. coronaria*. The range of this is from Canada to Alabama, west to Kansas and Texas. It is most abundant and most at home in the lower

Ohio Valley and just west of the Lower Mississippi. The fruit, while fragrant, does not ripen until very late, and does not lend itself well to the known habits of the apple maggot, especially the dependence of the larva on the mellowness of the pulp in order that it may mature readily. The probabilities do not appear to lie in the direction of native wild crabs as the original host of the apple maggot in America.

HAWS.

Of the native fruits now known to be attacked, the haws, *Crataegus* spp., seem to offer considerable probability of serving as the original host.

The maggot was early recorded from *Cratægus*. Walsh wrote his original description in part from adults bred from haws collected in Illinois about 1860 or 1861. Thus the first recorded food plant was the haw.

In 1872 Riley (52) spoke of the maggot as indigenous, feeding on wild haws or thorn-apples and on crabs. In the same article he expressed the wish that he might receive pupæ from the East in order to have adults "to place alongside of those in my cabinet which have been reared from wild haws and crabs here."

Comstock in 1882 (8) published a record of the occurrence of the insect in *Cratægus* at Washington, D. C., stating that the haws grew near an orchard but that the latter was not infested. The adults were reared and the identity established. Two years later Cook (9) wrote that the maggots were commonly found in haws in Michigan, Illinois and Wisconsin. Cordley, in 1889, stated that haws in Michigan were commonly infested.

Harvey in his monograph (25) states that he had not found the species in haws in Maine, where extensive studies were conducted, nor in Arkansas, where haws grow abundantly, nor in Iowa; but that he had found it abundantly in haws in northern New York.

Fletcher, in 1897 (16), wrote as follows: "In 1887 I bred the fly from haws found at London, Hamilton, Toronto, Montreal and Ottawa." He stated also that in 1888 haws at the Dominion Experimental Farms were badly infested.

Negative records were given by Quaintance in 1908 (51) who stated that in the preceding three years specimens of *Cratægus*

received from various parts of the country were not found infested; and by Illingworth in 1912 (34) who stated that "although careful observations have been made for two seasons at this station, no flies were discovered on haws here."

Ross in a preliminary report on investigations in Ontario (55) states that he examined many hawthorns in Durham and Hastings counties but "discovered no trace of the insect on them." Infested haws were received, however, from Ste. Anne's, Quebec, and from these larvæ and pupæ were secured.

In December, 1911, the writer learned through Mr. Lawson Cæsar, provincial entomologist of Ontario, that adults of the apple maggot had been reared from haws by Professor Swaine, then of Macdonald College. The trees grew in the vicinity of the college, and thus the specimens probably came from the same locality as the infested haws noted by Mr. Ross.

Further interesting facts were made available to the writer through the kindness of Mr. William H. Brittain, now provincial entomologist of Nova Scotia, and Professor T. G. Bunting of Macdonald College.

Mr. Brittain was formerly connected with the college and while there reared large numbers of the adults from a hawthorn hedge forming part of the eastern boundary of the college grounds. Apple trees of several varieties make up an orchard standing near this hedge. Some of the apples are distant but a few feet from the haws. In spite of this fact Mr. Brittain found no maggots in the apples at any time in the five-year period comprising his connection with the college and ending three years ago.

In a recent letter Professor Bunting states that some maggots were noted in 1913 in Tolmans and Yellow Transparents. None were observed in any other varieties that fruited last year, including McIntosh, Wealthy, Duchess, Fameuse, Patton's Greening, St. Lawrence, Montreal Peach, and several varieties of crab apples, although two or three of these, notably Fameuse, are varieties that ordinarily are attractive to the flies.

Correspondence with state and provincial entomologists has made available the following additional facts concerning the infestation of haws by the apple maggot.

In Nova Scotia Mr. Brittain, provincial entomologist, states that the maggot has been found abundant in wild haws in the

vicinity of Bear River, Digby County. It is of great interest to note that this is the section in which, somewhat recently, some orchards have been found infested.

Dr. H. T. Fernald of the Massachusetts Station writes that he captured one adult, September 17, 1910, ovipositing in the fruit of *Cratægus*, perhaps one hundred yards from the nearest apple tree.

In South Carolina Mr. A. F. Conradi states in a recent letter that he knows of one occurrence in haw.

What appeared to be the apple maggot has been noted repeatedly in haws in Michigan by Professor R. H. Pettit of the Michigan Station. Attempts to breed the adults were unsuccessful.

Professor J. Troop of the Indiana Station writes that the apple maggot has been found in haws in that state.

In Minnesota Professor A. G. Ruggles of the Minnesota Station states that the species is found in the state, having been bred from *Cratægus*, but that no damage has been recorded from apples.

There is thus locality record to date of the occurrence of the apple maggot in haws in Illinois, the District of Columbia, Wisconsin, New York, Massachusetts, South Carolina, Michigan, Indiana, and Minnesota, and in the Canadian provinces of Ontario, Quebec and Nova Scotia. In most of the above the identity was fully established.

Consideration of the haw as a possible original host discloses the fact that there are five or six species native to North America, the range of which is such that probabilities would lie in their direction (37, 56). Not all of these, however, have fruit of such character or season as would lend themselves well to the habits of the maggot.

With *Cratægus crus-galli*, which is found in New England and the central states but is most abundant in the lower Mississippi Valley, the fruit is likely to remain on the branches until spring, a habit ill-adapted to the apple maggot. The same is true of *C. tomentosa*, which in addition does not range much north of central New York. In the case of *C. coccinnea* and its near relative, *C. macracantha*, the fruit ripens in September or October, but generally hangs on the branches until after the leaves have fallen. The flesh is rather thin and dry. *C. punctata* has abundant fruit which, though dry and thin, ripens and falls in autumn.

In the case of *C. mollis* the fruit ripens early and falls at once, in September or October. The fruit is larger than that of some other species, and while mealy and thin is sweet. The characteristics of this variety and of the preceding three lend themselves to the present life history of the apple maggot.

HUCKLEBERRIES AND BLUEBERRIES.

There are two authentic instances of the occurrence of the apple maggot in huckleberries. The species was bred from this fruit in 1904 in Connecticut, and reported by Dr. Britton (2). A few years later it was reared in New Jersey from berries collected in the pine barrens of that state, the record being published by Dr. Smith (57).

In 1913 the apple maggot was found in blueberries in Maine. Mr. William C. Woods, representing the Department of Entomology of the Maine Station, collected infested berries in Washington County, which is a region of so-called "barrens." From these berries larvæ and pupæ were secured. From one pupa, kept in the laboratory, an adult emerged in February, 1914, and the identity was established. Infested berries were easily found in the section visited, though making up but a small proportion of the total. Berries in which the maggot was at work usually were shriveled, with red and stringy pulp. Adults were observed hovering around the bushes, and were collected and identified. Infestation was found in three species of blueberry, *Vaccinium pennsylvanicum*, *V. canadense*, and *V. vacillans*, including all of the species noted in the section where the observations were made.

No other published records of the occurrence of the apple maggot in blueberries are known to the writer. Infestation of this fruit has not been observed by any of the state entomologists, except in Maine. The records of the Bureau of Entomology, as transmitted in a letter from Professor Quaintance dated March, 1914, are equally negative.

In New Hampshire, the occurrence of the apple maggot in blueberries was definitely determined in the spring of 1914, following the receipt of an account of the discoveries in Maine, kindly furnished by the Maine Station. As a preliminary search, inquiry was made among a number of fruit growers who had

furnished valuable observations on the maggot in the course of the previous years. Twenty-seven growers stated that they had noted "wormy" blueberries, and a few described the condition in such manner as to lead to a surmise that the infestation may have been due to the maggot. There was no proof of course in any instance that this was certainly the case.

On the chance of securing further data a search was made for pupæ beneath blueberry bushes reported to have shown numerous wormy berries the prior season. The locality was Alton, N. H., and the dates were June 6 to 9, 1914. The variety of blueberry was the high-bush, *Vaccinium corymbosum*. In all 44 pupæ were found. One half of these were placed in moist sand in an incubator at 80 degrees Fahrenheit, and the other half in the open-air insectary. From each lot adults were secured and were identified as *Rhagoletis pomonella*. They were much smaller than the adults reared from pupæ derived from apples, or those observed around apple trees. The fact seems interesting that among the many adults noted or caught in the open around apples in the last four years, none were specially observed of the strikingly small size of the specimens reared from the pupæ from blueberries.

That blueberries or huckleberries may have been the original host of the apple maggot is conceivable. Both of these fruits are well represented in the flora of the northeastern United States (36). That their berries furnish sufficient food for maturing the maggot is demonstrated by the fact that numbers of pupæ were secured in the Maine experiments of 1913 and in New Hampshire in 1914.

Among blueberries there are the three species already noted, each of which is found through the greater part of the range of the apple maggot. In addition there is *Vaccinium corymbosum*, the highbush blueberry of the northeastern states.

Of huckleberries there are three species common in the northeastern states, *Gaylussacia dumosa*, *G. frondosa*, and *G. resinosa*. A fourth species, *G. brachycera*, is found in the central eastern states only.

DISTRIBUTION AND DESTRUCTIVENESS.

The present known distribution of the apple maggot approximates in general the limits of the eastern, or humid, part of the Transition Life Zone, in other words the so-called Alleghanian Zone. The area comprised within this zone, as defined by Dr. Merriam in 1900, is indicated in Chart 1.

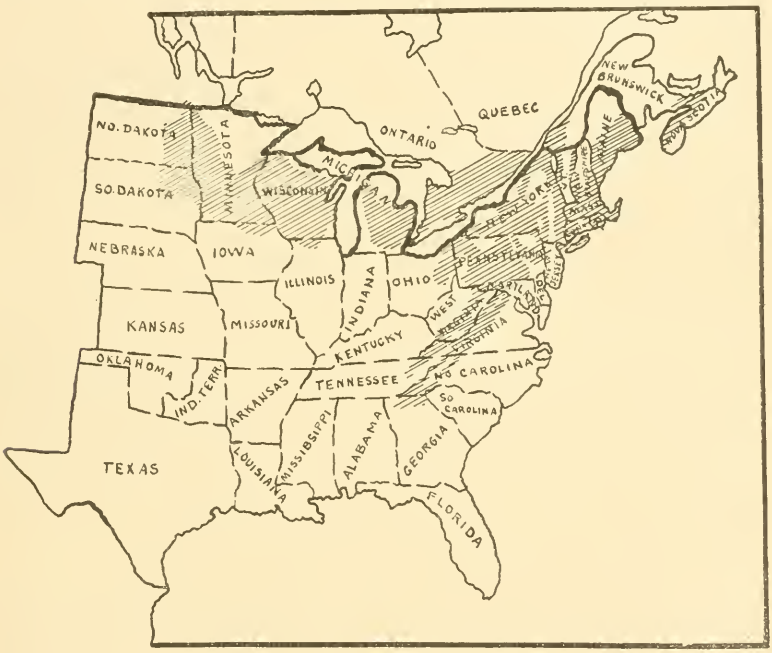


CHART 1. The Alléghanian Life Zone (shaded area). The known distribution of the apple maggot agrees approximately with this zone. For exceptions, and for details of distribution, see text.

The maggot reaches its greatest abundance and destructiveness in Maine, New Hampshire, parts of Vermont, in Massachusetts, parts of Connecticut and New York, with an additional wide, though scattering distribution in Ontario, Michigan and Pennsylvania.

Notes on the occurrence of the species in the several states and provinces have kindly been furnished the writer by entomologists. These are here summarized:

CANADA.

In Canada Dr. Hewitt, Dominion entomologist, writes that the apple maggot is common and injurious in certain sections in Ontario, Quebec and New Brunswick, and is known to be at work in Nova Scotia. The occurrence of the pest in any district is subject to considerable fluctuation from year to year.

In Ontario Mr. Lawson Cæsar has found the apple maggot in sixteen counties, ranging from Dundas, about twenty miles from Ottawa on the east, to Lambton County on Lake Huron. Only a small percentage of the orchards in any of these is infested and in some the insect has been found only in villages or towns. He thinks that further investigation will probably show that it occurs to a very limited extent in several other counties. The pest is worst in the district situated along the northeast part of Lake Ontario.

Professor Turney writes that in New Brunswick their records show the presence of the maggot in certain orchards at Woodstock, in Carleton County.

In Nova Scotia, Mr. William H. Brittain writes that the species is quite prevalent in parts of Digby County, in the southwestern part of the province. Specimens of infested fruit have been noted also in Yarmouth County, and it is probable that the pest has a wider distribution throughout the province than is at present known.

THE UNITED STATES.

The situation in Maine is summarized by Dr. Patch in the statement that the insect is the worst insect pest attacking the fruit of apple in the state, and that its range covers the whole apple growing territory.

A discussion of New Hampshire will be found later in this bulletin.

In Vermont Professor Cummings writes that the insect has caused much harm quite generally over the state, more particularly in orchards where sweet or semi-sweet apples occur. Other varieties are sometimes infested.

Dr. Fernald states that the maggot appears to be generally distributed over Massachusetts, and at least in some places is extremely abundant.

For Rhode Island Professor Stene writes that the species seems to be generally distributed over the state. Apple trees of early varieties apparently always show more or less signs of the presence of the pest. Late varieties are fairly free. Baldwin and Greening, if grown by themselves, and not in mixed orchards containing early varieties, are comparatively free from the insect.

Dr. Britton finds the maggot one of the more important pests of the apple in Connecticut.

In New York Professor Herrick writes that the maggot is apparently distributed all over the state. Complaints of it are few from western New York, but the reverse is true of the northeastern part of the state, where the species is a serious pest. In the experience of Mr. Parrott, also, the maggot causes little damage in the apple belt of western New York. The insect is a fruit pest in the state largely in "home" orchards, or in those that are not well cared for; but is reported frequently also from the northern part of the state and from elevated sections in the south.

In Pennsylvania Professor Stewart notes that the maggot exists in orchards over much of the northeastern part of the state. Professor Surface has found it destructive to summer and sweet apples in the northern part of the state and along the river courses southward. The area infested seems to be slowly spreading southward, especially along the water courses.

Dr. Headlee writes that the species has not been much complained of in recent seasons in New Jersey. It was recorded by Dr. Smith as locally injurious in summer varieties at Montclair, in the highlands section of the state.

In Delaware the maggot is not known to occur. The same is true of Maryland.

In Virginia the species is rare. Dr. Alwood did not observe the insect in Virginia during the time when he was engaged in entomological work.

Mr. Sherman has not observed the maggot in North Carolina, but believes it quite possible that it occurs in the mountain sections of the state. In *Insect Life*, Vol. VII, p. 279, it is stated that larvæ of *Rhagoletis pomonella* were observed in an apple received from Waynesville, N. C.

For South Carolina Professor Conradi states that the species

is found in the apple orchards of the piedmont section of the state. The annual damage is estimated at not to exceed 2 per cent. The maggot is considered a species of little consequence.

There are no authentic observations of the presence of the maggot in Georgia or in Florida.

In Michigan Professor Pettit writes that they are troubled somewhat by the apple maggot, but not excessively. What appears to be the same species occurs commonly in crabs and haws.

Professor Sanders states that in Wisconsin the species has never been of any considerable importance. Its work has not been generally noted, though more infestation was found in 1913 than in the previous three years.

In Minnesota the maggot is not a pest, according to notes furnished by Professor Ruggles. No damage has been recorded from apples, although the species has been bred from *Cratægus* in the state.

A letter from Professor Waldron states that in North Dakota they have not found the maggot. Apple growing is so new an industry in the state that very few of the pests have as yet put in an appearance.

For South Dakota Professor Severin states that the insect has not been recorded in the state.

For Iowa Professor Webster reports no recent damage, although a number of years ago it was found in injurious numbers in the state by Professor Osborn. It is not now common.

Professor Swenk writes that there is no authentic instance of the presence of the species in Nebraska, nor has attack on Nebraska grown apples been observed.

In Kansas the species has been observed occasionally in orchards in the eastern part of the state, according to notes by Professor Dean, but it has not proved a serious pest. It does not seem to be any more abundant than it was several years ago.

Professor Gillette writes that he has never seen the work of the insect in Colorado. About twenty years ago a fly was taken by him in general collecting at Colorado Springs that was determined as this species. It was probable that the maggot or pupa had been shipped to that locality in a barrel of apples from the East.

In none of the states farther west has the species been observed at work.

For Ohio Professor Gossard states that but little damage is done by the maggot. An apple is occasionally noted that has been mined by it, and there are sometimes reports that it (presumably this species) has been doing considerable damage in an orchard here and there.

In Indiana Professor Troop has found the species to some extent. It is not considered such a universal pest as the codling moth and some other species, but in certain seasons and in certain regions or sections of the state it makes itself felt almost every year.

In Illinois Dr. Forbes writes that he has never seen a specimen of the maggot in the state, or any evidence of its occurrence. It is not represented in the collections of the state.

South of the Ohio River definite observations of the occurrence of the species are lacking.

In the southwest the only positive observations are from Arkansas. Professor Becker writes that it was once thought that the pest occurred there, but that he could not confirm this from personal observation. A recent letter from Dr. Hinds transmits the information from Professor Walker, formerly horticulturist of the Arkansas Station, that he has seen in the Ozark region, Arkansas, a little of the work of an insect that he takes to be the apple maggot.

ECONOMIC STATUS IN NEW HAMPSHIRE.

The economic position of the apple maggot in New Hampshire may be summarized as follows:

It is one of the important, destructive and persistent apple insects of the state. It is found throughout the state, wherever the apple is grown commercially. It has infested apples more or less in the greater part of these areas for many years. Its damage fluctuates widely from year to year, remaining invariably most persistent in early fruit and showing the widest variation in winter fruit. The general circumstances in the state as regards the condition and care of the ordinary farm orchard and as regards the prevalence of infested wild apples, are exceed-

ingly favorable to the pest. In most orchards the damage goes essentially unchecked. In a few it is well under control.

BLANKS SENT TO GROWERS.

In the winter of 1909–1910, following a year of excessive abundance of the apple maggot, a circular letter was addressed to about 300 fruit-growers, representing practically all sections of the southern two thirds of New Hampshire. This is the part of the state in which the apple is grown commercially.

In this circular information was asked along the following lines:

the amount of injury from the apple maggot in the neighborhood, and whether injury is increasing;

the number of trees infested in the orchard of the correspondent, and the location and surroundings of the same;

the length of time that the trees had been infested;

the practice of the owner in the matter of permitting sheep, pigs, cattle or chickens in all or part of the orchard;

how long live stock remained under the trees in the fruiting season, and the possible benefits of this practice;

the existence of wild apples near the orchard, and the infestation of the same by the maggot;

the practice of the owner in the matter of picking up drops in his orchard;

the surroundings as regards neglected trees infested by the maggot;

the practice of the owner in the matter of ordinary spraying or other treatment for insect pests.

With this circular was included a list of varieties of apples commonly found in New Hampshire orchards, which the grower was asked to check off to show the conditions in his locality in the matter of susceptibility of different varieties.

Two hundred and twenty-two replies were received from these circulars, the correspondents being located in 129 towns in the state, representing all sections. The location of these points is shown in Chart 2.

Following this, further correspondence was conducted; from time to time, other growers were consulted; additional circulars were sent out, and with a proportion the preliminary inquiry

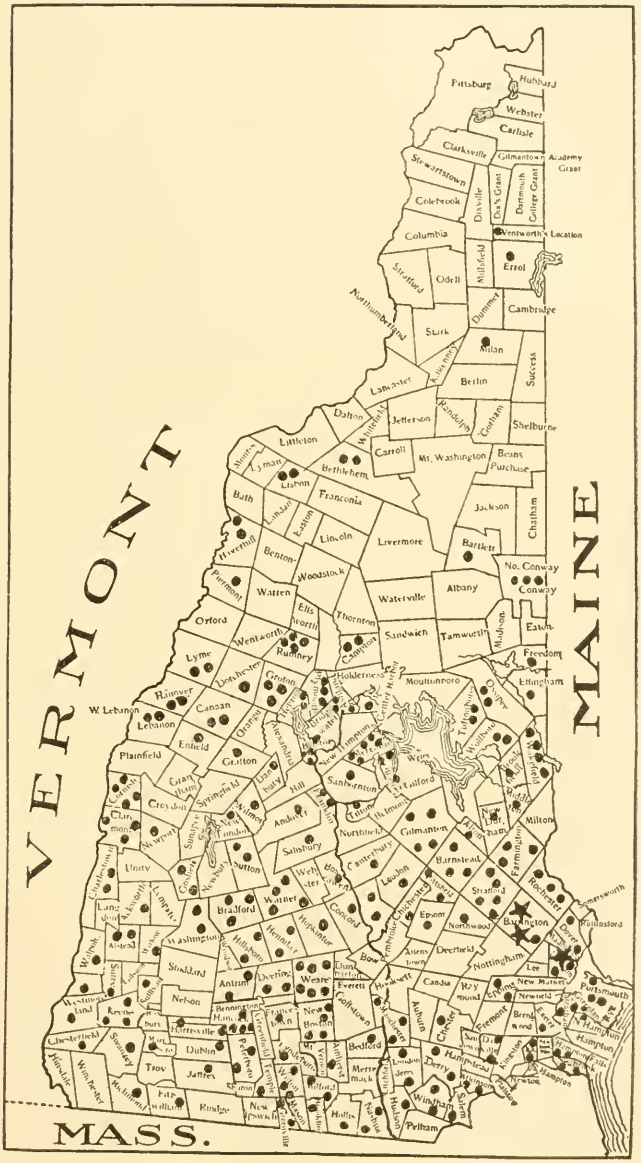


CHART 2. Location of observation points in apple maggot studies. Stars indicate location of major experiments.

was followed at later dates by one or more trips by the writer or his assistants in order to make personal observations and to study in detail some of the interesting facts indicated.

DISTRIBUTION OF THE MAGGOT IN NEW HAMPSHIRE.

The maggot was found in all localities visited or inquired into, up to the northern limits of commercial apple growing in the state. It is not equally prevalent in all of these towns, but is some factor in all and a considerable factor in most.

The northernmost point at which the maggot was personally observed was the town of Jefferson, immediately north of the White Mountains. It was abundant in an orchard visited at that point. Some apples are grown in neighboring towns, but these were not visited. In the town of Milan, twenty miles northeast of Jefferson, there are but few apple trees and the maggot is reported not to infest them. In Errol, fifteen miles north of Milan, a few apples grow, and some have been set out five miles still farther north, but the maggot has not been observed by the growers. In Colebrook and Dixville, forty miles directly north of Jefferson, a few apple trees grow. No observations are at hand to show whether they are infested or not.

LENGTH OF TIME ORCHARDS HAVE BEEN INFESTED.

One hundred and ninety-five growers gave an estimate as to the length of time that infestation had been noted in their orchards.

Of these 44, or 22.6 per cent, placed the time indefinitely at "several" or "many" years; 47, or 24.1 per cent, had noted their apples infested for five years or less; 35, or 17.9 per cent, placed the time at ten years or less, but more than 5; 31, or 15.9 per cent, gave it as fifteen years or less but more than ten; 24, or 12.3 per cent, had noted infestation for twenty years or nearly so; 8, or 4.1 per cent, had observed the maggot for twenty-five years or nearly so; 2 had seen its work for thirty years; 3 for more than thirty years; 1 for forty years. These estimates were made by growers in 1910. Allowing for the fact that infestation undoubtedly existed in many orchards for some time before it was specially noted by the grower, for a natural tendency to underestimate the time elapsed when the period is a long one, and for the fact

that in many instances the grower at present in charge of an orchard or farm was not resident there or not actively interested in the subject fifteen or twenty years before, it will be seen that probably the apple maggot was somewhat generally to be found in New Hampshire orchards in early fruit twenty or more years prior to 1910, and in many sections certainly was in evidence at a much earlier date.

The grower who reported that he had observed the pest in apples forty years before was Mr. F. S. Slayton of Lebanon, a town in the western part of the state, in the Connecticut Valley. Since this statement was made in 1910, the date when the maggot was noted by this grower would be 1870, which is prior to the first published record of infestation in New Hampshire (52).

An interesting comment on the first appearance of the maggot was offered by Mr. Bela Chapin in a letter to the writer in February, 1910. Mr. Chapin lives in Claremont, N. H., in the Connecticut Valley. He said: "When the maggot first appeared here about twenty-five or thirty years ago the orchards by the river on low land were first affected, and it was all of five years from the maggot's first appearance in town that it appeared in my orchard."

A third correspondent reporting in 1910 that the maggot had been injurious in his orchard for more than thirty years lives in Londonderry, in the southeastern part of the state. A report of infestation for thirty-five years prior to 1910 came from Goffstown in southern New Hampshire. Other early records were received from Weare, Wakefield, Goshen, Canterbury, Tilton, Gilmanton, Hanover, Bristol, Alton, and Chesterfield, representing various sections in western, central, southern and eastern New Hampshire.

PREVALENCE OF WILD APPLES, AND INFESTATION BY THE MAGGOT.

The existence of infested wild or seedling apples in the neighborhood of orchards is obviously a possible factor in persistent infestation by the maggot, if such apples are neglected, which is usually the case.

Out of 195 growers sending in reports on this subject, 139 stated that wild apples, or "natural fruit" as these trees are termed, grow in the vicinity of their cultivated trees. Fifty-six

reported that wild apples do not grow near their trees. Of the latter, however, a considerable number are to be accounted for because the grower lives in a village or other somewhat closely settled community.

Our study of the question seems to warrant the statement that wild apples are more or less prevalent throughout practically all of that part of the state in which the apple is grown commercially, except in the few towns bordering on the Atlantic Ocean. In the latter there is an occasional tree, but they are scarce. In a great many towns wild apples are exceedingly common, occurring at comparatively remote points in wooded areas as well as in pastures and fields. In fact, on numbers of farms part of the cultivated apples are seedling trees that have been grafted, the trees left standing where they sprang up, or transplanted into rows.

One hundred and twenty-five growers offered observations as to infestation of wild apples by the maggot. Of these 103 stated that the wild fruit near their orchard was infested; 22 stated that it was not.

In general it is unquestionably true that seedling apples, especially such as drop and become soft before freezing weather, are infested.

AMOUNT OF DAMAGE, AND SEASONAL FLUCTUATIONS.

Of 222 growers, 182, or 82 per cent, reported in 1910 that in the preceding two or three years there had been much damage by the maggot. Eleven growers, or 5 per cent, stated that there had been "some" injury. Fifteen growers, or 6.7 per cent, defined the injury by limiting it to early apples. Fourteen growers, or 6.3 per cent, stated that there had not been much injury in their neighborhoods.

A considerable number offered the observation that the injury varies from year to year, being excessive in seasons when the apple crop is short following years of heavy crop. In a number of cases it was argued, as the writer believes correctly, that a year of large apple crop is favorable to the maggot, while at the same time distributing the injury by it over much fruit, so that it is not so much in evidence; that a year of light crop following this gets the benefit of an unusually large number of adult flies ready for

egg-laying. In turn a heavy crop the second year following is apt to show light infestation.

As bearing on this point it is interesting to note that 39 growers, in the course of their reports for the year 1909 but without the question being asked, noted that 1909 was a year of exceedingly light yield of fruit. That it was a year of great abundance of the maggot was amply demonstrated. It has also been fairly well ascertained that the two or three years preceding 1909 were, in most sections, years of fair to large yields of fruit.

Following 1909 there were again seasons of larger yields, and the damage by the maggot diminished, until, in 1912, it became in some sections noticeably less numerous than it had been. This was followed by an excessively light yield of fruit in 1913, due to wide-spread late frosts, and again in 1913 injury by the maggot became severe, with frequent heavy infestation of winter fruit. The relation of the abundance of the pest to severe attack on late varieties of apples will be noted later.

COMPARATIVE ATTACK ON CULTIVATED APPLES.

In the winter of 1909–1910 a blank was submitted to growers on which were listed 65 varieties of cultivated apples, including all that were known to be grown to any extent in New Hampshire.

The grower was asked to indicate opposite the name of each variety his observations or experience as to the amount of damage by the maggot to that variety in his neighborhood, marking each in one of three ways to show that it was (1) known not to be infested, or (2) known to be moderately infested, or (3) known to be badly infested.

It should be especially noted that these reports were asked for at the end of a season of great abundance of the maggot in most localities. The net results of this questionnaire represent, therefore, something like the maximum infestation. Some varieties here listed as attacked are in many cases free from attack in seasons of less abundance.

Two hundred and ten growers filled out the blank. A summary of their report is given in Tables 1 and 2.

TABLE 1.

Comparative Attack on Cultivated Apples According to Variety in a Season of Abundance of the Maggot.

Summarized from reports from 210 growers, winter of 1909–1910.

Variety.	Number of Growers reporting variety as:			
	Not attacked.	Moderately attacked.	Severely attacked.	Total.
August Sweet or Sweet Bough	1	74	73	148
Bailey Sweet or Sweet Winesap	3	8	3	14
Baldwin	72	81	9	162
Ben Davis	37	11	2	50
Benoni	1	3	3	7
Black Oxford	2	1		3
Blue Pearmain	62	15		77
Chenango	1	1		2
Danvers Sweet	3	12	5	20
Early Harvest	6	37	41	84
Fallawater	11	3		14
Fall Harvey		6	4	10
Fameuse	9	38	31	78
Foundling	1	5	3	9
Franklin Sweet	2		1	3
Gano	5	1		6
Gravenstein	30	63	18	111
Granite Beauty	1	4	1	6
Garden Royal	1	8	11	20
Garden Sweet		4	5	9
Grimes	5	7	6	18
Golden Russet	28	26	8	62
Haas	4	2		6
Haskell		3		3
Hawley		1	1	2
Hubbardston	13	67	29	109
Hurlbut		6	1	7
King	26	51	19	96
Lady	1	6		7
McIntosh	31	27	3	61
Maiden Blush	21	15	1	37
Mann	23	10	1	34
Milding	2	3	3	8
Minister	1	5	6	12
Moody			2	2
Munson Sweet	1	2	5	8
Nodhead or Jewett Red	8	28	25	61
Northern Spy	21	58	50	129
Oldenburg	18	24		42
Peach	6	8	1	15
Porter	8	65	94	167
Pound Sweet or Pumpkin Sweet	12	86	32	130

TABLE 1—(*Concluded*).

Variety.	Number of Growers reporting variety as: Not attacked.	Moderately attacked.	Severely attacked.	Total.
President		6	2	8
Primate		1	2	3
Red Astrachan	43	71	26	140
Red Canada	9	4	6	19
R. I. Greening	44	60	13	117
Rolfe	3	1		4
Rome	1	1		2
Roxbury	48	30	5	83
Sops of Wine	7	36	16	59
Spitzenburg	14	25	14	53
Stark	3	3		6
St. Lawrence	1	8	1	10
Tolman Sweet	5	31	30	66
Twenty Ounce	5	27	9	41
Wagener	7	4		11
Wealthy	12	21	3	36
Westfield or Seek No Further	5	5	3	13
Williams Favorite	6	27	4	37
Winesap	2	2	1	5
Winthrop Greening	2	1		3
Yellow Bellflower	23	26	6	55
Yellow Transparent	18	18	9	45

TABLE 2.

Varieties in Order of Comparative Freedom from Attack.

Based on reports from 210 growers in a season of abundance of the maggot. (Varieties reported by less than ten growers have been omitted.)

Variety.	Percentage of reports stating not attacked.	Season of ripening.	Characteristics.
1 Blue Pearmain	80.6	Fall—Oct.	Skin thick—mild—subacid
2 Fallawater	78.6	Late fall—Nov.	Skin tough—subacid to mild
3 Ben Davis	74.0	Winter	Skin tough—mild subacid
4 Mann	67.7	Winter	Skin moderately thick—tough—hard—subacid
5 Wagener	63.7	Late fall	Skin thin—tough—subacid
6 Roxbury	57.9	Winter	Skin moderately tough—sprightly subacid
7 Maiden Blush	56.8	Fall—Sept.—Nov.	Skin thin—tough—subacid
8 McIntosh	51.9	Fall—Sept.—Oct.	Skin thin—tender—subacid
9 Red Canada	47.4	Winter	Skin tough—mild subacid

TABLE 2—(*Concluded*).

Variety.	Percentage of reports stating not attacked.	Season of ripening.	Characteristics.
10 Golden Russet.	45.2	Winter	Skin thick—moderately tender—subacid—aromatic
11 Baldwin.....	44.5	Winter	Skin tough—subacid
12 Oldenburg	42.9	Early fall—late Aug.—Sept.	Skin moderately thick—tender—subacid
13 Yellow Bellflower	41.9	Winter	Brisk subacid
14 Peach.....	40.0	Winter	Skin tender—thin—subacid—brisk
15 Yellow Transparent	40.0	Summer	Skin thin—tender—sprightly subacid
16 Westfield	38.5	Fall	Skin tough—mild subacid
17 R. I. Greening.	37.7	Winter	Skin moderately thick—tough—subacid
18 Yellow Newtown	33.4	Winter	Skin tough—aromatic—subacid
19 Wealthy.....	33.4	Late fall to early winter	Skin thin—tough—mild—subacid
20 Red Astrachan	30.8	Summer	Skin thin—tender—brisk subacid
21 King.....	28.1	Late fall—Oct.—Dec.	Subacid—aromatic
22 Grimes.....	27.8	Winter	Skin tough—subacid—aromatic
23 Gravenstein...	27.1	Fall—Sept—Nov.	Skin thin—tender—subacid—aromatic
24 Spitzenburg ...	26.5	Winter	Skin tough—sprightly subacid—aromatic
25 Bailey Sweet ..	21.5	Winter	Skin tough—sweet
26 Northern Spy .	16.3	Winter	Skin thin—tender—subacid—aromatic
27 Williams Favorite	16.3	Early fall	Skin thin—tender—mild subacid—aromatic
28 Danvers Sweet	15.0	Late fall—Nov.	Skin thin—tough—sweet
29 Fameuse.....	14.1	Fall—Oct.	Skin thin—tender—mild subacid to sweet
30 Nodhead.....	13.2	Late fall—winter	Skin thin—tough—mild subacid to sweet
31 Twenty Ounce.	12.2	Fall	Skin thick—tough—subacid
32 Hubbardston .	12.0	Late fall	Mild subacid to sweet
33 Sops of Wine .	11.9	Summer	Skin thin—tender—mild subacid
34 St. Lawrence ..	10.0	Fall	Mild subacid
35 Pound Sweet ..	9.2	Late fall	Skin thin—tough—very sweet
36 Minister.....	8.4	Late fall to winter	Tender—juicy—pleasantly subacid
37 Tolman Sweet	7.6	Late fall	Skin tough—very sweet
38 Early Harvest	7.2	Summer	Skin thin—tender—mild subacid to sweet
39 Garden Royal .	5.0	Summer	Skin thin—mild subacid—aromatic
40 Porter.....	4.8	Early fall	Skin thin—tender—subacid—aromatic
41 August Sweet	0.1	Summer	Skin thick—sweet—slightly aromatic
42 Harvey.....	0.0	Fall	Rich subacid—high flavor

OCCURRENCE OF EARLY VARIETIES IN NEW HAMPSHIRE ORCHARDS.

Consideration of Table 1 discloses some facts of interest suggestive of the relative abundance of certain varieties of fruit in the sections covered by these reports. It should be remembered that the grower was asked to let his report indicate conditions as regards fruit free of attack as well as that attacked, as he knew them in his neighborhood. It is a reasonable inference therefore that the grower checked off in most cases all or most of the varieties to be found in his own and neighboring orchards.

The twelve varieties on which reports were received, postively or negatively, from the largest number of growers were as follows, listed in order of number of reports received:

Porter, Baldwin, August Sweet, Red Astrachan, Pound Sweet (or Pumpkin Sweet), Northern Spy, R. I. Greening, Gravenstein, Hubbardston, King, Early Harvest, and Roxbury.

Of these 12 varieties, 6 are summer or fall fruit, and out of these 6 there are 5 varieties notoriously severely attacked by the apple maggot, namely, the Porter, August Sweet, Pound Sweet, Hubbardston and Early Harvest. The fact that fruit of this character is so commonly to be found somewhere on many New Hampshire farms is a factor of consequence in the persistence and destructiveness of the maggot.

SOME FACTORS INFLUENCING COMPARATIVE INFESTATION BY VARIETIES.

In Table 2 the 42 varieties reported on from 10 or more orchards are listed in their order of comparative freedom from infestation by the maggot, according to the experience of the growers reporting, together with brief remarks concerning the date of ripening of the variety and the characteristics of the fruit, as given by Beach (1).

Early Ripening. Later in this bulletin, under a discussion of the comparative mortality of eggs and larvæ of the maggot in various varieties of apples, observations will be found indicating the marked adaptability of early ripening fruit to the life economy of the maggot, and the equally marked absence of such adaptability in the case of the harder winter varieties. The date when a variety ripens, therefore, or more especially its habit of falling

early and of mellowing soon after it falls, is a factor of importance in the continued infestation of that variety by the maggot.

In Table 2 it will be seen that of the first 11 varieties in order of freedom from infestation not one is early fruit. Of the last 10 varieties on the list, representing maximum comparative infestation, 7 are summer fruit or begin to drop early.

Aroma. Early maturity is not, however, the only factor. The aroma or flavor of the fruit is unquestionably of much influence in comparative attack; the varieties with sweet flesh or with aromatic flavor suffering worst.

Thus the Tolman Sweet, though a fruit of late fall, ranks toward the bottom of the list. The same is true of the Pound Sweet and the Nodhead. Other late varieties such as Northern Spy, Bailey Sweet, Spitzenburg, Gravenstein, Grimes and King, doubtless owe a certain measure of their infestation to their aroma, though in part to other causes. Taking the reverse condition we find that Yellow Transparent, distinctly a summer fruit, has brisk subacid flesh and is often comparatively free of attack.

Thickness of Skin. Apparently the thickness of the skin is a factor, perhaps because the flies find it more difficult to puncture, perhaps because a thick skin permits less of the aroma to escape. Of the first 12 varieties on the list in order of freedom from infestation 11 have a tough or a thick skin.

Characters in Combination. Considering the characters in combination we find that fruits possessing two or three of the above qualities favoring infestation are likely to rank near the bottom of the list. Those which have place at the top of the list are marked by possession of two or three of the reverse of these characters.

Location near Susceptible Varieties. A fourth condition bringing about many reports of infestation of a variety is the comparative abundance of that variety in the average New Hampshire orchard, which in turn carries with it a probability that on the average farm there will be some trees of this abundant variety located near susceptible early or sweet fruit. It has frequently been observed in the course of our work that trees of varieties not favorable to the maggot that stand close to a tree of highly susceptible variety are prone to attack, especially in seasons when the early tree bears sparingly or not at all.

It has already been noted that among winter apples Baldwin, Northern Spy, R. I. Greening and King are in comparative abundance in New Hampshire orchards, especially Baldwin. Undoubtedly these varieties, notably the Baldwin, are often found infested in part because of the condition indicated above.

LIFE HISTORY STUDIES IN NEW HAMPSHIRE.

For the most part the life history studies here described were carried on at one or more of three places, as follows: in the vicinity of Durham; in a section known as Beauty Hill, seven miles northwest of Durham; and at another point known as Sunnyside, two miles farther northwest.

The altitude at the latter two places is greater than that of Durham, which is about thirty feet above sea level, and the summer season usually begins appreciably earlier and lasts longer. Other conditions in the three places are about the same, and do not differ materially from conditions at most other points in southern New Hampshire. Some observations were made at various other points in the southern half of the state.

The cages and other apparatus will be described in the discussion of the various experiments in which they were employed.

Nearly all the life history work was performed in the open, in or about orchards, under conditions and surroundings believed to be entirely normal. Some experiments, as noted in the discussions that follow, were carried out in the open-air insectary belonging to the department of entomology. This building is fully described in the *Journal of Economic Entomology*, Vol. 2, page 389. In brief the work-room has screen sides and a double canvas roof with air-space between. The floor is partly of concrete, partly earth that is continuous with the ground beneath. Moisture appears normal in this earth at a depth of a few inches. Temperature and humidity in the work-room are normal. In winter, in these experiments, the canvas roof and screen sides were removed.

THE ADULT—DATES OF EMERGENCE.

In New Hampshire normal emergence of adults of the apple maggot begins the first week of July. When the season is advanced, or when other conditions tend to accelerate emergence,

flies may begin to appear the last week in June. In late seasons, or when other conditions tend to delay emergence flies may not begin to appear until the second week in July. The flies normally emerge in largest numbers in the second and third weeks in July. This is approximately true even when the beginning of emergence has been delayed, in this case the flies appearing in rapidly increasing numbers as soon as emergence is once started. In the last week of July the number of flies appearing quickly diminishes to a small fraction of the figures for the period preceding, and is practically at an end by the middle of August, but straggling individuals may continue to appear from time to time throughout the latter month. In New Hampshire there is no second period of emergence in August or at any other time in the latter part of summer. There is no evidence of a second brood.

Emergence in 1910. Partial records only were secured in 1910 showing the dates of emergence of adults.

In experiments to determine the depths from which adults can make their way out, pupæ were buried at various depths in the soil. These were not in normal surroundings as regards sunlight. Emergence of adults from these pupæ began July 9, and was at the approximate maximum about July 15.

In June, 1910, a ground cage was placed in the open in Strafford, N. H., over soil containing numerous pupæ. An apple tree had stood at this place the previous year, but had been cut down. The cage used had wood sides and top, with two mica chimneys fixed in holes in the top. Adults were noted in the chimneys on June 30. This and succeeding records at this point were not made by members of the department.

Emergence in 1911. In the summer of 1910 preparations were made for observing the dates of emergence of the adults in 1911 by placing 13 lots of badly infested apples in heaps on the ground, and allowing these to rot undisturbed. Twelve of these lots were on sod and one on cultivated ground.

In addition, on June 19, 1911, 200 pupæ were buried just beneath the surface in 8 of the lots. These were miscellaneous pupæ secured in the course of experiments of the previous fall.

In order to secure the adults emerging, cages were placed over each location. All adults were removed daily, except on three dates. All cages were at least three feet square and had

screen wire tops. Part of the cages had wood sides, part screened sides. Spiders or other visitors were carefully removed as found. Dirt was banked around the bottom of each cage to prevent escape of any adults.

The locations varied from deep shade to partial shade in 9 of the lots. The remaining 4 lots were in the open. All were in the village of Durham.

The records of emergence of adults from these lots are given in Table 3. Of these the first column gives the total daily emergence from the 9 lots in whole or partial shade; the second column gives the emergence from the 4 lots in the open. The weather notes attached are taken from the records of the local weather bureau.

TABLE 3.

Emergence of Adults in 1911 at Durham.

Date.		Emergence from 9 cages in whole or partial shade.	Emergence from 4 cages in the open.	Weather records.			
				Max. temp.	Min. temp.	Precipitation.	Character of day.
June	21			68	49		Clear
	22			74	54		"
	23			73	60		"
	24			77	47		"
	25			69	44		"
	26	16	30	75	51		P. cloudy
	27	19	28	74	57		Cloudy
	28	23	30	76	59		"
	29	29	16	84	60		Clear
	30	47	24	80	55		"
July	1	14	12	90	57		"
	2	4	25	94	64		"
	3	19	3	103	68		"
	4	9		103	73		"
	5	44	8	97	72		"
	6	*	*	102	72	.62	Pt. cloudy
	7	92	62	83	68		Clear
	8	12	81	84	50		"
	9	40	52	94	58		"
	10	3	2	101	68		"
	11	49	1	100	73		"
	12	100	1	98	73		"
	13	121	16	87	61		"
	14	128		72	60		"
	15	22	14	86	59		"
	16	*	*	83	59		Clear

TABLE 3.—(*Concluded.*)

Date.		Emergence from 9 cages in whole or partial shade.	Emergence from 4 cages in the open.	Weather records.			
				Max. temp.	Min. temp.	Precipitation.	Character of day.
July	17	*	*	72	63	.21	Cloudy
	18	288	61	83	64		Clear
	19	122		87	56		"
	20	*	*	83	49	.21	Pt. cloudy
	21	73	29	77	54		Clear
	22	62	2	85	54		"
	23	*	*	84	55		"
	24	60	8	84	61	.51	Cloudy
	25	16		77	60		Clear
	26	25		82	49		"
	27	5		80	52		"
	28			67	55	2.75	Cloudy
	29	*	*	73	58	.54	"
	30		1	77	57	.12	Pt. cloudy
	31	2		92	57		Clear
Aug.	1	2		81	61		Clear
	2	2		64	55		Cloudy
	3			73	58		"
	4	2		80	55		"
	5			77	49		Clear
	6			76	57		"
	7			82	58		"
	8	2		75	58		Cloudy

On dates marked * adults were not removed.

Other emergence records for 1911 will be found in the discussion of the duration of the pupal state, as summarized in Table 24. These records are from pupæ kept in soil in flower pots in the open-air insectary. Emergence from these began June 28 and ended August 20. The maximum was reached from July 7 to 25.

Further 1911 records were secured in connection with experiments with fowls as a means of destroying pupæ and flies. In these cases pupæ were buried in the soil beneath the screen wire cages in which the fowls were confined. These cages were in the open. Some flies from these pupæ escaped the fowls and were recorded, the first on June 26, the last on July 8.

In records showing the emergence from pupæ buried at various depths in the soil in 1911 adults began to appear in numbers

on June 28, there having been a single earlier emergence on June 22. The emergence was practically at an end by the middle of July.

Emergence in 1913. In the summer of 1912 preparations were again made for securing normal emergence records in 1913. The arrangements were similar to those made for the 1911 records. Piles of infested apples were placed on the ground, on sod, and allowed to rot. In June, 1913, screen wire cages were placed in position and the adults removed daily as found. Emergence was recorded from six such cages.

Three of these cages, comprising Lots 1, 2 and 3, were located in whole or partial shade. Each cage was made of a light wood framework covered with screen wire. Lots 4 to 6 were wood cages with screen wire tops and stood in the open. The apples beneath the latter cages were of miscellaneous character, but a considerable proportion were late fruit, such as Tolman Sweet.

The emergence is summarized in Table 4, together with the corresponding weather records from the data of the local weather bureau. The first three columns represent the records of Cages 1, 2 and 3, where the variety of apple and date of placing were definitely recorded. The fourth column is the total of cages 4, 5 and 6, where miscellaneous apples were used but a considerable part of them late fruit.

It will be seen that emergence began July 10, quickly reached a maximum from July 15 to 23, and rapidly diminished at the close of the month, with scattering records from time to time through August, up to August 22.

Note should be made of the fact that all of June and the first third of July were characterized by extreme drought. The total rainfall June 1 to July 9, inclusive, was .20 inch, this precipitation occurring June 21.

Additional emergence records for 1913 will be found in Table 25, in which are summarized the records of adults maturing from two-year-old pupæ. With these it will be noted that the first adults appeared July 11, and emergence was completed July 29, these dates agreeing in general with those in Table 4.

TABLE 4.

Emergence of Adults in 1913 at Durham.

Date.	Emergence from August Sweets in partial shade. Apples placed Aug. 8, 1912.	Emergence from Porters in shade. Apples placed Sept. 3, 1912.	Emergence from Early Harvests in partial shade. Apples placed Aug. 8, 1912.	Emergence from 3 lots in sun.	Weather Record.			
					Max. temp.	Min. temp.	Precipitation.	Character of day.
July 5					95	68		Cloudy
6					90	65		Clear
7					75	54		"
8					81	51		"
9					85	48		"
10	13		14		82	49	.10	Cloudy
11	1		8	1	80	53		Clear
12	16		28		83	45	.01	"
13	1		6		90	47		"
14	7		20	12	74	63		"
15	3		31	38	77	54		"
16	7	3	44	35	78	59		Pt. cloudy
17	6	1	33	7	85	50		Clear
18			3	3	73	63	.15	Cloudy
19	6	11	39	19	85	56		Clear
20	4	2	21	1	86	54		"
21	5	4	8	2	80	55	.56	Pt. cloudy
22	7	30	11	13	84	52		Clear
23	1	22	8	6	90	56		"
24		1	2	3	85	67	.08	Cloudy
25	2	18	2		77	60		Clear
26	1	15			87	47		"
27		2			89	52		"
28	1	3			87	57	.06	Cloudy
29		8	2	3	87	64		Pt. cloudy
30			1		90	61		Clear
31		5		2	95	60		"
Aug. 1					71	52		Pt. cloudy
2	1	1			75	63	.02	Cloudy
3					91	53		Clear
4					85	58	.67	Cloudy
5					72	54		Clear
6		1			79	52		"
7	1				83	53	.04	Cloudy
8					76	51		Clear
9					78	52		"
10					85	64	.03	Pt. cloudy
11					86	51		Clear
12					73	49		"
13			2	1	74	48	.10	Pt. cloudy
14				1	73	55	.01	Clear
15					82	44		"
16					95	52		"
17	2				94	54		"
18					95	63		Pt. cloudy
19			1		86	50		Clear
20	1	1			86	43		"
21					75	38		"
22		1			81	45		Pt. cloudy

ONE BROOD ONLY.

In the life history studies carried out in New Hampshire in the last four years there has been no evidence observed of a second brood. In the course of the work large quantities of infested early as well as late apples have been under observation, and the pupæ secured from these have been retained under varying conditions for use in further work. In one experiment alone more than 14,000 pupæ were under observation and record. In all, large numbers of pupæ have thus been recorded, many of which were kept in such surroundings that if any adults had emerged from them the same season in which pupation occurred they would hardly have escaped detection. Considerable quantities of such pupæ, numbering into the thousands, were kept in closed receptacles in the open, other thousands were within the open-air insectary, where they were entirely surrounded with wire screening. In no case was any emergence observed the same season with any of these many thousands of individuals, where retained under conditions of normal temperature.

Early in the work, where some pupæ were kept in dry soil in a basement room, development was accelerated and flies emerged early. These pupæ, however, were in artificial warmth, and in addition the soil containing them was in a glass jar exposed to sunlight, a condition which in itself would materially raise the temperature. Their emergence was considered abnormal.

The following experiments afford additional evidence.

In 1912 two lots of infested apples shown in Table 4 as No. 1 and No. 3 were secured as early as possible, and kept under observation.

Lot No. 1 consisted of about three-fourth bushel of August Sweets. These came from the Sunnyside locality, where the season tends to be earlier than at Durham. The fruit was badly infested, and maggots were beginning to mature. These apples were placed on sod August 8, 1912, beneath the shade of a small linden tree at Durham. A large screen-wire cage was placed over them. The cage was kept under careful observation until November 15. No flies emerged in 1912. In 1913 86 adults appeared, as given in detail in Table 4, column 1.

Lot No. 3 were Early Harvest apples. This variety is one of the earliest of the summer apples, and one of the first to grow

mellow. The apples were secured from the Beauty Hill locality August 8, 1912. The lot consisted of about three-fourth bushel. The fruit was badly infested and maggots were maturing. The apples were placed on sod at Durham, under an ash tree, in partial shade. They were covered with a screen wire cage and maintained under careful observation until November 15. No flies emerged in 1912. In 1913, 284 flies emerged in this cage. The detail emergence record of these is given in Table 4, column 3.

In 1913 various lots of infested apples were brought to Durham for the counting of egg punctures in connection with other experiments. These included 6 lots of Porters. The dates when the lots were collected were August 20, 2 lots, August 21, 4 lots. These were placed on sod, in the open, and covered with wire screen cages. No flies appeared from these in 1913.

Two special lots of early infested apples were secured in 1913, brought to Durham, and kept under careful observation to detect any emergence of adults the same season, if such took place. One lot consisted of August Sweets, collected at the Beauty Hill locality and brought to Durham August 5, 1913. The other consisted of an early sweet apple of unidentified variety and were collected August 12, 1913. In both cases the apples were well infested with maggots. Each lot was placed on undisturbed soil in the open. Each was covered with a large cage of screen wire. The cages were kept under careful observation through the remainder of the season. No flies were observed in either cage.

Further south in the range of the apple maggot it is possible that a partial second brood may occur. Illingworth (34, p. 147) describes some experiments conducted at Ithaca, N. Y., in 1911 in which adults emerged in September and October. Six experiments are noted. In five of these, the first, second, third, fifth and sixth, it is stated that the experiments were conducted in the insectary, or that the soil containing the pupæ was covered with a "cylinder jar," or both. If a glass insectary of enclosed type is referred to, abnormal temperatures would probably occur within during midsummer. If the "cylinder jars" were of glass and received any direct sunlight, similar abnormal conditions would follow. It appears possible, therefore, that in these experiments development was accelerated and the emergence

noted was not normal. Further reference to this possibility will be found in the discussion of the length of the period after emergence before egg-laying.

In the remaining experiment, the fourth, apples were placed under a field cage which was located beneath an infested apple tree, thus affording, unfortunately, opportunity for extraneous results. The months of July and August, 1911, were marked by extreme heat at Ithaca and elsewhere.

In another part of the same bulletin, page 162, incidental record is made of the fact that adults emerged in September and October in certain other experiments. These were from pupæ that were kept in conditions not normal as a feature of the experiments in hand.

The experiments are interesting, but the evidence appears to the writer insufficient to warrant general assumption that the apple maggot is two brooded.

Certainly in New Hampshire there is no indication of a second brood, and there is much evidence that none exists.

INFLUENCE OF TEMPERATURE AND MOISTURE ON RATE OF EMERGENCE.

A suggestion of the possible influence of moisture and of temperature on the rate of emergence of the adults will be found in the detail records for 1911 and 1913 given in Tables 3 and 4, though definite conclusions may not be drawn because of the part that other factors may play.

In 1911 9 lots were in whole or partial shade and 4 were in the open. Emergence in the former apparently reached its maximum July 12 to 14, with further heavy emergence on the 19th and probably on the 18th. In the latter the maximum apparently came July 7 to 9, although there was an apparent increase again on the 18th. Seemingly the period of rapid emergence in the cages in shade lasted a few days later than in those exposed to full sunlight. In the records for 1913, however, there is no clear ratio.

In 1911 no attempt was made to secure flies from the cages during rainfall, since they were found and secured with difficulty. There was, however, an apparent increase in the rate of emergence following rain. In 1913 such flies as could be found and secured

were collected on days of rain. In this year there seems to be an evident acceleration of emergence immediately following rainfall, even though the precipitation was slight. Further, the month of June was one of great drouth in 1913, the total rainfall being only .20 inch up to July 10. There had been no emergence noted up to that date. With a slight precipitation on July 10 emergence began.

Extreme heat seemed to retard emergence of the flies or perhaps to kill many of them before they were collected in the daily examination of the cages. Thus the records on July 3 and 4, 1911, when the temperature rose to 103 each day, fell off in marked degree. The same was true on July 10, 1911, with a temperature of 101.

MANNER OF EMERGENCE OF FLIES.

At various times from June 29 to July 6, 1911, observations were made of the behavior of flies on emergence from the ground.

On first coming to the surface flies are vigorous and active. They are as yet light in color, and the wings are not expanded. For a time they crawl around rapidly, seemingly searching for a suitable place for expanding and drying the wings. Occasionally one will jump, somewhat like a spider. In spite of their activity, however, flies that fell on their backs seemed unable to right themselves, and died.

The length of time required for the wings to expand and dry varied from forty-three minutes to an hour. Usually about forty-five minutes was needed.

The flies did not attain the normal dark color until about an hour after the wings were expanded, and flight was not much indulged in until this additional period was over. Thus the total length of time from the first appearance above ground to active, normal flight was an hour and a half or more.

PERIOD AFTER EMERGENCE BEFORE EGG-LAYING BEGINS—MINIMUM LENGTH.

In 1911 and again in 1913 repeated and somewhat elaborate attempts were made to maintain newly emerged flies under definite observation for an extended period in surroundings as

nearly normal as possible. Much difficulty was experienced in accomplishing this. In fact, the larger the cage built, and the more nearly the conditions appeared to approach normal, the more apt the flies were to refuse to live out their existence to full period and in rational manner.

Nevertheless some egg-laying was done, and definite facts were ascertained as to the possible minimum length of the period after emergence of the female before egg-laying may begin. These facts were both unexpected and interesting.

It was proved that in some instances at least the length of this period may be less than one week. In one case, in 1913, a fertile egg was laid by a female only four days after emergence. In 1911 there was one definite case of a six-day period, and one of an eight-day period. In the few other cases where definite results were secured the period was longer; it is of course possible that in these instances the females concerned were ready to begin egg-laying earlier. Very few eggs were laid in total, or at least very few were detected.

It is not assumed from this that the normal length of this period is one week or less; but it is certain that the period may be this brief on occasion and that the two to three weeks hitherto assumed as the approximate minimum does not always prevail.

Experiments in 1911. In 1911 four dwarf apple trees, standing about four feet high and located in the college orchard at Durham, were enclosed in screen wire cages. Each cage was 3 feet 4 inches square on the ground and 4 feet high. In one side was a small door.

Beginning June 29, 1911, flies were released in these cages. The flies placed in each cage were newly emerged from pupæ secured the previous year. All flies released in a cage on a given date were of the same day's emergence, and no others were released in this cage until all of the first lot had died or been removed. In each cage at frequent intervals apples were placed that were known to be free from infestation, the apples having been bagged as they hung on the trees before any emergence of flies had taken place. These apples were tied to the limbs of the dwarf trees within the cages. Apples remained in the cages for two to six days, and were then removed and placed on soil in

order to favor hatching of any eggs deposited and development of larvæ. The varieties of apples used included Early Harvest, Yellow Transparent, Spy and Baldwin.

In Cage No. 1, 13 females and 12 males were released on June 29, the day when they emerged. All died or disappeared by July 18. Meanwhile, however, two eggs had been laid in an Early Harvest apple placed in the cage July 15 and removed July 19, giving a minimum period of not exceeding twenty days.

In Cage No. 2, 14 females and 12 males were released on June 29, the day that they had emerged. The last of these disappeared or died by July 18, but one egg was laid in an Early Harvest apple placed in the cage July 6 and removed July 7, and one egg each in two Early Harvests placed in the cage July 7, and removed July 8. The minimum period here established, therefore, was not to exceed eight days.

In Cage No. 3, 12 females and 9 males were released on June 30, the day on which they had emerged. These flies had died or disappeared by July 18. One egg had been laid in a Spy apple placed in the cage July 3 and removed July 6, thus establishing a minimum period not exceeding six days.

In cage No. 4, 15 females and 9 males were released on June 30, the day on which they had emerged. These lived no longer than those in the other three cages. One egg was laid in a Yellow Transparent apple placed in this cage July 6 and removed July 10, giving a minimum period in this instance not exceeding eleven days.

At another point in the college orchard a large cage covered with cheese-cloth was erected over a standard apple tree. This cage measured 12 by 12 feet square, and 12 feet high. Twenty-five females and 7 males were released in this cage June 28, 1911, and were supplied with apples changed at frequent intervals, as in the other cages already described. In spite of the elaborate preparations the flies in this cage died or disappeared within three weeks. Apparently no eggs were laid in the apples hung to the tree in this cage.

Experiments in 1913. In 1913, 5 rearing cages were set up in the open-air insectary. Each cage was 12 by 12 inches square, and 24 inches high, and each was placed on soil. The frame-work and top of the cages was wood, the sides and back

cheese-cloth, and the front glass. In each cage was placed a lot of flies that had emerged on a given date. Moisture was provided in each cage. One apple was supplied in each cage and as a rule, was changed daily. The apple was cut in half so as to present freshly exposed surface on which flies might feed. The fruit used was known not to be infested. It was secured from North Carolina and from California. As they were removed, the sections of apple were placed on soil to observe development of larvæ from any eggs that might have been laid in them.

The flies in these cages lived longer than those in the tree cages of the previous year. The record for each lot is given in detail in Table 6.

Some eggs were laid by the flies in these cages. The sections of apple removed were placed on soil. This soil was kept intact, but was not examined for pupæ or empty pupal cases until April, 1914. The results of the examination were as follows:

In Lot 1, an egg was laid in a section of apple that was in the cage for one day, twenty-six days after the flies emerged and were placed in the cage. The larva developed to the pupal stage.

In Lot 3, consisting of 8 females and 6 males emerged and placed in the cage July 17, an egg was laid in a section of apple that was in the cage July 21, the larva developing to the pupal stage. Thus there is established in this instance a possible minimum period after emergence before egg-laying of not to exceed four days. Also 2 eggs were laid in a section that was in the cage August 4, the larva developing to pupation.

In Lot 4, an egg was laid in an apple that was in the cage for one day, nineteen days after the flies emerged and were placed in the cage. The larva developed to the pupal stage.

In Lot 5, an egg was laid in an apple that was in the cage for one day, sixteen days after the flies emerged and were placed in the cage. The larva pupated.

All flies used in the 1913 experiments were from 1911 pupæ, representing the two-year phase in the life cycle of the species, as discussed later in this bulletin.

Comparison with Results of Dissection of Flies. Illingworth (34, p. 143), in daily dissection of flies found that twenty to twenty-four days were required after emergence before ripe eggs were found in the egg-tube. The flies used were those that

had emerged in late summer, and ascribed to a second brood. It has already been suggested, in the discussion of the number of broods, that these flies may have represented accelerated development, rather than a normal second brood. If this were the case it would not be surprising to find that these females were sexually comparatively immature. The fact that the dissections cited showed a period of this length appears to the writer additional indication that this may have been the case.

PROCESS OF EGG-LAYING.

The manner of egg-laying was carefully studied and described by Harvey (25, p. 209). It was again observed and described by Illingworth (34, p. 142). Our observations of the process do not differ from those cited, except in the average length of time required, which probably would vary with the time of day and temperature, and the activity of the fly.

At first the fly runs around over the surface of the fruit as if searching for a place to its liking. Sometimes it turns around several times. The thorax is then turned downward, the sharp ovipositor extruded, and the point thrust through the skin of the apple. The ovipositor is worked up and down, rapidly at first and then slowly. After the egg is placed the fly walks away, then stops and cleans the ovipositor with the hind legs.

The entire process, from beginning to end, was sometimes completed in approximately one minute, but usually occupied from two to four minutes, and in one instance the total time occupied, including the preliminary trials and the cleaning of the ovipositor, was seven minutes and forty-two seconds.

The egg-puncture is roughly circular in outline, and at first is decidedly inconspicuous, but later is readily distinguishable with the naked eye.

The egg is deposited slightly beneath the skin of the fruit, somewhat at an angle rather than vertically, and with the pedicel end toward the surface of the fruit.

CHOICE OF VARIETIES FOR EGG-LAYING.

Although many experiments were carried out in which apples of diverse varieties were made available for egg-laying to flies

in cages, large and small, the results are not sufficient in number to warrant conclusions.

On the basis of many field observations, however, it is clear that the flies prefer sweet or aromatic fruit. This is shown in the summary of comparative attack on various varieties and the discussion of the characteristics of those attacked. So long as such fruit is available the females will continue to oviposit in it until individual apples may be fairly peppered with egg-punctures. When such fruit is not available the females oviposit irregularly and scatteringly. It has repeatedly been observed in New Hampshire orchards that a tree of sweet or aromatic variety standing among varieties of acid or subacid character will to a considerable extent hold the attention of the females so long as the fruit is available. If such a tree drops its fruit early, or fails to fruit, the neighboring trees will then be attacked, but not with the undivided attention accorded the favorite variety.

Flies Captured on Early Fruit Confined with Late Fruit. That flies that are found about early fruit are able, though perhaps not especially willing, to oviposit in late fruit, was demonstrated in the following experiment:

In 1910 several clusters of apples on Spy trees at Durham were enclosed in cheese-cloth bags prior to the beginning of emergence of adults. On August 9 several flies were captured in an Orange Sweet tree, an early variety, the fruit being then nearly ripe. The next day one pair of these flies was confined in each of two of the limb-bags, and 7 flies in a third. In each of the first two bags 1 apple was found with 1 egg puncture. In the third 1 apple had 1 puncture, 1 had 2, and 1 had 4.

NUMBER OF EGG PUNCTURES PER APPLE.

In the course of the investigation there has been occasion to examine large numbers of apples critically for egg punctures. Many thousands of specimens were thus observed and recorded. Detail records of various lots will be found elsewhere in this bulletin, especially in the discussion of experiments with poison bait sprays. It will be noted that the number of punctures per apple sometimes reaches a high average—a fact not surprising to one who has observed badly infested fruit.

In general, if the fruit in question is of sweet flavor or attractive aroma, there seems to be only one factor of consequence determining the number of punctures per apple. That factor is the relative abundance of female flies in or about the tree as compared with the amount of fruit available. If the circumstances of previous seasons have brought about a large supply of flies, and if there is a less than ordinary amount of fruit, the fruit is apt to be most thoroughly punctured. If the reverse is the case, infestation is likely to be slight.

The maximum number of egg punctures found in any one apple in the entire investigation was observed in a lot of Porters picked September 10, 1913. The entire lot was badly infested, many apples having more than 20 punctures each. One apple in the lot had 46 punctures. This is a tree that had been sprayed with poison bait, receiving 7 applications from July 9 to September 6. The detail record will be found in the discussion of poison bait spraying.

PERIOD DURING WHICH EGGS ARE LAID.

As noted in the discussion of the length of the period after emergence before egg-laying begins, flies may begin to lay eggs within a week or less after they emerge. Thus, with emergence beginning under favorable conditions the last week in June, or under circumstances that tend less toward acceleration the first or second week in July, the beginning of the egg-laying period may be set down as the first to the fifteenth of July in the average.

Through the experiments described below, with field observations to corroborate the results, it is certain that the end of the egg-laying period does not come until well into September, or probably until frosts and other climatic conditions bring to a close the life of the female flies.

In 1910 an egg-laying period was definitely proved extending from July 4 to September 19, inclusive, a total of seventy-eight days.

Experiments in 1910. The following preparations were made in 1910 for securing data as to the length of the period during which egg-laying may continue in an ordinary orchard.

In an orchard at Durham two Tolman Sweet trees were selected, and bags of cheese-cloth were placed over clusters of

apples before the beginning of emergence of the flies. In an orchard at the Sunnyside locality similar preparations were made with 5 trees of the following varieties: Red Canada, a variety known locally as Sweet Longworth, Baldwin, Maiden Blush and August Sweet. Each orchard had a record of bad infestation by the apple maggot.

Beginning with June 27 one bag was removed on each tree, and the fruit was allowed to remain exposed for one week. At the end of that time the bag was again placed in position, that particular cluster of fruit remaining enclosed for the remainder of the season. At the same time a bag was removed on another cluster which was given its week of exposure to egg-laying flies; and so on through the season.

There was of course considerable dropping of apples within the bags, and the fruit did not ripen in normal manner or with normal color. Nevertheless the apples were found by flies, eggs were laid, and it was demonstrated that in the season in question the egg-laying period began not later than July 4 and ended not earlier than September 19. The earliest recorded emergence of flies in 1910 was June 26. This was beneath an infested apple tree, and in normal surroundings.

The detailed record of the bagged clusters is given in Table 5.

TABLE 5.

Egg-Laying in Bagged Clusters Exposed for Periods of One Week.

(Each cluster remained bagged throughout the remainder of the season.)

Dates exposed.	Tolman Sweet.		Tolman Sweet.		Red Canada.		Sweet Longworth.		Baldwin.		Maiden Blush.		August Sweet.	
	No. apples.	No. punctures.	No. apples.	No. punctures.	No. apples.	No. punctures.	No. apples.	No. punctures.	No. apples.	No. punctures.	No. apples.	No. punctures.	No. apples.	No. punctures.
June 27–July 4	6	5	10	28	12	7	11	3	12	5	8	1	3	0
July 4– 11	10	12	11	4	15	6	9	0	16	9	10	6	0	0
11– 18	8	7	10	31	13	9	7	2	20	10	3	3	7	23
18– 25	10	17	7	9	35	18	11	3	2	0	6	2	3	36
25–Aug. 1	8	13	11	10	6	0	14	4	11	8	13	6	1	5
Aug. 1– 8	9	23	12	41	9	2	12	0	9	9	9	3	1	7
8– 15	7	6	8	8	12	19	5	0	9	8	4	1	2	11
15– 22	7	8	7	11	9	2	7	4	6	1	8	12		
22– 29	3	11	6	7	20	120	9	4	7	2	4	21		
29–Sept. 5	8	5	6	9	8	0	6	2	9	4	14	10		
Sept. 5– 12	8	24	12	60										
19– 26	4	12	8	13										

Field Observations. In field observations flies have repeatedly been observed well into September. On September 9 many flies were noted in and about a Tolman Sweet tree. Other similar observations were made.

No difficulty was experienced September 5 and 7, 1911, in finding females engaged in egg-laying. The process was watched, the eggs marked, and larvæ hatched from the eggs.

Harvey (25, p. 206) states that in Maine egg-laying continues until the flies die in the fall by killing frosts. Females taken by him about the middle of September were dissected, and were found to contain eggs in varying stages of development.

EGG-LAYING PERIOD OF INDIVIDUAL FEMALES.

Efforts to maintain individual females under observation throughout the entire length of their normal egg-laying period were unavailing. Definite data were not secured on this point.

Harvey (25, p. 207) dissected the female genitalia, and from the number of eggs and the developmental stages concluded that egg-laying must extend over a considerable time. Illingworth (34, p. 143) made careful dissections, tracing the development of the egg, and concluded that flies are able to continue ovipositing during the remainder of their active existence, after egg-laying is once begun.

Egg-Laying in Fallen Fruit. In no case were flies ever observed laying eggs in apples that had dropped from the tree. In normal surroundings flies were never seen on or near the ground, except at the time when they were emerging.

LENGTH OF LIFE OF THE FEMALE.

The longest period during which an individual female was kept alive in confinement was thirty-three days. This was in 1913, in rearing cages set up in the open-air insectary. The type of cage and the manner in which the flies were handled has been described in the discussion of experiments of that year to determine the length of the period after emergence before egg-laying. The detailed results are given in Table 6. No method was discovered by which flies could be kept alive in natural surroundings for a period that could be assumed to equal the maximum or even the normal.

TABLE 6.

Length of Life of Flies in Rearing Cages in 1913.

Date.	Lot 1, 7 males, 7 females, emerged July 15. Total dead.	Lot 2, 2 males, 5 females, emerged July 16. Total dead.	Lot 3, 6 males, 8 females, emerged July 17. Total dead.	Lot 4, 12 males, 8 females, emerged July 22. Total dead.	Lot 5, 4 males, 2 females, emerged July 25. Total dead.
July 17	2				
18	3	1			
19		3			
20					
21	4	4	1		
22		5	2		
23				7	
24	5			8	
25		6			
Aug. 4	11		5	18	3
8	12				
10	13				
11			7		
12				20	
13			9		
14					4
15			10		
17			12		
18			13		6
19			13		
Maximum length of life	26 days	11 days	33 days	21 days	24 days
Notes:	1 fly escaped July 17	1 fly alive when discontinued			

In the large field cages used in 1910, 1911 and 1913, the period was still shorter. To take an example, in 1913, in connection with other experiments, flies were confined in two special cages, each of which enclosed a dwarf apple tree. Each cage measured 6 feet 4 inches by 6 feet by 6 feet high, and was covered with fine mesh screen wire. The floor of each cage was covered with moist sand, over which was stretched sheeting securely fastened to the bottom of the cage. A barrier of tanglefoot prevented ingress of ants small enough to pass through the meshes of the

screen. Apples were provided. The sheeting over moist sand afforded moisture. Spaced lath over the top of the cages gave partial shade. In spite of these precautions flies introduced into these cages lived but a few days.

Ross (55) also found difficulty in keeping females alive in confinement under conditions intended to be as nearly normal as possible.

Illingworth (34, p. 150), by confining the flies in inverted jelly glasses and giving them careful attention, kept some alive for six weeks from the time that they were captured in the open, and others, reared in late summer, to a maximum of fifty days.

It is certain that in nature individuals live longer than the maximum recorded in our experiments. What the natural maximum may be is not known.

DISPERSION HABITS OF THE ADULTS.

The results of many records and field observations through the four seasons of this investigation may be summarized in the following conclusions.

There is apparently a tendency on the part of the adults of this species to remain in the immediate locality where emergence took place. Although the flies are certainly able to travel considerable distance, there does not seem to be, ordinarily, any marked dispersion instinct at any point in the adult stage, such as exists with many other insects.

Adults emerging beneath a tree bearing sweet or pleasantly aromatic fruit appear likely to remain in or about that tree. This is true whether the fruit is an early maturing variety, well suited to the life economy of the maggot, or whether it is of late variety, so that actually comparatively few of the larvæ hatching in it develop to maturity.

When the fruit of an early variety has fallen, with adults still in existence about the tree, or when there is failure to fruit, the flies then appear to disperse. If there is another fruiting tree of acceptable variety near they are apt to find it and to concentrate their attentions on it, though the direction of winds and such matters seem to have an important influence on the manner and direction of dispersion. If the remaining trees near by are not of the preferred varieties there is likely to be scattering infestation, without apparent concentration on any one tree,

although here again the direction of winds and similar matters may play an important part.

Adults emerging beneath fruiting trees of the less acceptable varieties, such as the subacid fruits, seem to follow the same general habits as described in the last paragraph, concentrating their attention largely on any preferred variety near by, or dispersing in general fashion in the lack of such variety.

In localities where much early and neglected fruit grows, and in a year when there is a light crop of fruit following a season of abundant opportunity for increase of the maggot, especially if early fruit has failed, the combined results of forced dispersion of adults from non-fruiting acceptable varieties may approximate a general dispersion.

Basis of Conclusions. The above conclusions are drawn from observations and field notes by the writer and his assistants during the last four years, and from the experiences of growers. Space will not permit reproducing these notes in this bulletin in the detail that would be necessary to render them of any value.

In general it may be stated that, repeatedly, instances were found where trees of like susceptibility, located often within a short distance of one another, showed marked difference in the extent of infestation by the maggot. Often such trees were of the same variety, and frequently the difference in infestation persisted in similar manner from year to year. Usually, the trees remaining free of the maggot were so located that drops were cleaned up by livestock, or the fruit used up clean by the owner, while the infested trees received the reverse treatment. In some cases the practice of an orchardist in the matter of care of his fruit, including disposal of drops and spraying, appeared to give him practical immunity from the maggot, while his neighbors, perhaps located not more than a quarter of a mile away and with similar varieties, following careless methods, suffered severely from the maggot.

The deduction naturally made from such observations was that the adults of this species tend distinctly toward localization.

On the other hand, certain localities were found where something like general dispersion of the adults seems to come about practically every season. These localities appear to be characterized by an excessive amount of early or neglected fruit, or both.

From these experiences the deduction was made that such surroundings may bring about an approximation of a general dispersion.

Experiments in 1911 and 1913. In 1911 and in 1913 various experiments were undertaken intended to furnish direct data as to the dispersion habits of the flies. It was hoped to prove how far they might or might not travel, but evidence of a precise nature was not obtained.

In the first experiment, at the Beauty Hill locality, 76 flies were released beneath one of a small group of late trees. Later 100 apples from this tree were examined and 12 egg punctures found. From a tree fifty feet away 100 apples were examined, and 14 egg punctures found. Other trees in the group gave similar results.

In a row of Baldwin trees along a stone wall at Durham 75 flies were released beneath one of the trees July 7, 1911. An examination of the fruit later showed the following records. From the tree beneath which the flies were released 176 apples gave 263 punctures; from a tree twenty-five feet away 96 apples gave 88 punctures; from a tree twenty-five feet away in the opposite direction 125 apples gave 47 punctures; from a tree fifty feet away 137 apples gave 214 punctures; from a tree seventy-five feet away 158 apples gave 50 punctures. There is of course no proof that the egg punctures found were the work of the flies released.

Other similar experiments at two other points at Durham gave similar indefinite results, which could be interpreted, if at all, as merely indicating that the flies released beneath late trees did not concentrate and lay an abundance of eggs in the fruit of the tree in which they were let loose.

In August, 1913, an experiment was tried of releasing marked flies. One hundred flies caught in apple trees in the Beauty Hill locality were marked by amputation of one leg of each. These flies were then released 350 feet from a small orchard owned by the station. The wind was blowing moderately toward the orchard. Search in the orchard for marked flies was made at intervals for several days, but none were observed.

In a similar experiment later 50 flies marked in the same manner were released 200 feet from the orchard, the wind blowing steadily at the time toward the point of observation. No flies were recovered in the orchard.

ATTRACTION TO BAITS, AND FEEDING.

Many observations, together with the results of experiments described in paragraphs that follow, as well as the results of extended trials of poison bait sprays and of poison trap pans, lead to the conclusion that the adult flies of this species are not noticeably attracted to any one of a variety of substances that ordinarily prove strongly attractive to many other insects.

The substances tried included, among others, sugar, glucose and molasses, which serve as a compelling lure for other species, such as the housefly. In no case did such baits prove notably attractive.

Observations of feeding habits in the open, under normal conditions, were as follows:

When a fly is resting on an apple it has been observed to extend its proboscis and touch the surface of the fruit. Probably this is for feeding on such substances, found on the skin of the apple, as can be taken up by the mouth parts, although there is no definite proof that this is the case. If an apple is cut, so as to expose fresh pulp, flies seem moderately attracted to it.

Flies noted in other parts of trees, especially when resting on leaves, were not observed to give any indication of feeding.

The impression of the writer, and of others connected with the work of this investigation, is that in general the flies feed rather sparingly, so far at least as daylight hours are concerned.

Experiments in 1909. At the beginning of the investigation in 1909 an apparatus was arranged by which it was hoped to secure data on the reaction of the flies to substances that might be used as baits.

This device consisted of two glass bell-jars, the bottoms of which were fastened together. One bell-jar was covered with black paper and was directed away from the light. In the farther end of this was fitted a glass cylinder. The substances to be tested were placed in this cylinder. Later the device was modified by arranging the two bell-jars as before with bottoms fastened together, but with both jars uncovered. The two were placed parallel to the source of light. In the end of one jar was fitted a glass cylinder containing distilled water; in the end of the other was the substance being tested.

Ten flies were used in the tests with the first apparatus. The substances tried and the results recorded were as follows:

Five c.c. water containing 10 drops of 95 per cent alcohol. One fly in cylinder at the end of twenty hours.

Ten drops 95 per cent alcohol, 10 drops acetic acid and 2 drops amyl valerianate. No flies in cylinder at the end of two hours.

Twenty-three flies were used in the tests with the modified apparatus. The substances tried, with the results recorded, were as follows:

Five c.c. distilled water containing 10 drops 95 per cent alcohol. No result at end of two and a quarter hours.

Five c.c. distilled water containing 10 drops acetic acid. No results.

Five c.c. water containing 3 drops amyl valerianate. No results at end of two and one half hours.

Pure coal oil. One fly in cylinder at end of three hours.

Five c.c. water containing 1 drop acetic acid and trace of amyl valerianate. Two flies in cylinder at end of one half hour.

Experiments in 1911. In 1911 arrangements were made for confining flies in observation cages, and offering them leaves dipped in sweet solutions that might prove attractive. With these solutions was mixed arsenate of lead in the same proportion used in some of the field tests of poison bait sprays.

The flies were secured from large numbers of adults emerging in the concrete bins in the open-air insectary. Infested apples had been placed on earth in these bins the previous season. Emergence of the flies began a few days early, apparently being somewhat accelerated by the warmth absorbed by the concrete bins, which, earlier in the season, had been exposed to sunlight.

The cages were 12 by 12 by 24 inches, with glass fronts and cheese-cloth sides. The flies were provided with water.

June 19 and 20, 1911, the following cages were started, with the results indicated:

Cage 1, 10 flies. Leaves offered were dipped in a solution of molasses 1 part, water 4 parts, arsenate of lead at the rate of 1 ounce to 1 gallon. Record: all flies dead at the end of five days.

Cage 2, 8 flies. Leaves offered were dipped in a solution of molasses 2 parts, water 4 parts, and arsenate of lead as before. Record: all flies dead at the end of five days.

Cage 3, check, 10 flies. Apple leaves offered, but not dipped in any solution. Record: all flies dead at the end of five days.

Cage 4, 7 flies. Apple leaves offered dipped in solution of glucose 2 parts, water 8 parts, arsenate of lead as in cages 1 and 2. Record: all flies dead at the end of five days.

Cage 5, check, 6 flies. No apple leaves dipped in solution were offered. Record: 5 flies dead at the end of four days; remaining fly sluggish and removed.

To see if further information might be secured, use was made of the flies emerging in three of the concrete bins, by offering in each case a branch of apple leaves dipped in a solution of glucose, water, and arsenate of lead. The presence of the sweet apparently had no appreciable effect on the behavior or welfare of the flies. On occasion, flies would be observed on the leaves, but they seemed not to be attracted to them in any noteworthy fashion, and no special results were discernible from such attention as they paid them.

Other Corroborative Experiments. The long-continued experiments with poison bait sprays described later in this bulletin are essentially field tests on an extended scale of the response of the flies to the ordinary sweetened baits. The results of these tests are believed by the writer to offer conclusive data on the subject.

Harvey (25 p. 223) described tests of baits tried by him. A bait was prepared of sweets poisoned with arsenious acid and corrosive sublimate. This was placed on paper in shallow pans in the trees. It failed to attract the flies. Sticky fly paper was tested, several sheets being hung in the branches of a tree where flies were numerous. Only one apple maggot fly was caught.

Ross (55 p. 68) tried poisoned molasses spread on the branches; also tanglefoot traps sprayed with the essence of pear, peach and banana, and with citronella oil; and tin pans containing poisoned cider, essence of pear, citronella oil, and kerosene. No results were obtained, except with kerosene, when 7 pans caught a total of 28 flies.

GENERAL BEHAVIOR OF ADULTS.

Perhaps the most notable characteristic of the adult flies is their sluggish behavior. They are not normally active or nervous. It is seldom difficult to capture a specimen by quietly placing the open mouth of a small vial over it as it rests on a leaf

or on fruit. They can be caught with the thumb and finger. On a sunny day, under conditions that would be expected to quicken activities, they are more alert, but even here the sluggish trait is rather pronounced.

Flies disturbed by the collector do not dart away for an instant to return shortly to the same spot, but if they do take their departure seem usually to fly upward toward higher parts of the tree, and to remain there.

It cannot be said that the flies invariably prefer either sunshine or shade. They are found in both situations. In 1910 100 apples were picked from a Porter tree at Durham. Fifty of these were selected from sunny parts of the tree; 50 from shaded parts. Examination of the fruit showed 117 egg punctures in the apples from the sunny situations and 168 punctures in the apples from shade.

The observation has been made by one or two who have studied the species and by a number of growers that the flies seem not to thrive in locations exposed to strong winds. This may be true under some circumstances; but it is the belief of the writer that usually there are other factors in such instances, notably the varieties of fruit concerned, or sometimes the fact that uninfested trees standing on hill-tops are in pastures, where live stock keep the drops picked up. The reverse condition often accounts in part for bad infestation of trees located in sheltered situations near to farm buildings.

THE EGG.

The position of the egg in the apple has already been noted in the discussion of the process of egg-laying.

The duration of the egg stage was observed in 1911 by noting adults at work laying eggs, and marking the puncture. The fruit was then removed for further observation. The time of hatching was determined in two instances. In each the period was five days. This was in early September.

Ross (55), in a series of similar determinations found a period of four and three fourths to nine days, with an average of six. This was under normal surroundings.

Illingworth (34, p. 144) observed an incubation period of two to six days. In this case the eggs were removed from the apple

after deposition and were placed in apple pulp, in a hollow glass slide in a moist chamber; it is possible, therefore, that the normal period was somewhat shortened.

The mortality of the egg, in our investigations, was noted in conjunction with that of the larva. The varying percentages of mortality of these two combined will be found discussed in some detail under observations on the larval stage.

Ross (55), by examination of a large number of egg punctures, found an average percentage of dead eggs, including infertile eggs, ranging from 17.1 per cent to 34.9 per cent.

THE LARVA.

On hatching from the egg the larva immediately begins to penetrate the pulp of the fruit, following no direct course, but wandering about in every direction, sometimes working just beneath the skin or again penetrating to the neighborhood of the core. At first the tunnel is very small and not easily made out. Later, if the condition of the pulp is favorable to the development of the larva, the tunnel walls turn brown and are conspicuous. When several larvæ are present in a single fruit of mellow pulp the tunnels may coalesce, and the greater part of the fruit may be broken down, although the apple may show, on the outside, comparatively little sign of its condition.

When apples of hard pulp are attacked, such as many winter varieties, either the larva develops very slowly on hatching, or within a short time development ceases entirely and the larva may die. If such fruit chances to fall early, and if it grows mellow before cold weather arrives, development of the larva may then pass on rapidly to maturity.

Immediately on completing its growth the larva leaves the apple in order to enter the ground for pupation. A certain mellowness of the pulp is necessary in order that the larva may mature. This condition is not fully reached, under normal conditions, until the fruit has fallen from the tree. The exit of the larva therefore, does not normally take place until a longer or shorter period after the fall of the apple.

PERIOD BETWEEN FALL OF APPLE AND EXIT OF LARVÆ.

The length of the period between the dropping of the fruit and the exit of the larvæ is a matter of much concern, economically,

if control measures are to be directed toward this phase of the life cycle. For this reason a part of the investigation was arranged with a view toward securing considerable data on the varying lengths of this period and the factors that may bring about variations.

An account of the manner in which the data were secured is given below in the discussion of Experiments in 1910. The list of varieties studied, together with the season of each, is given in Table 7. The detailed record of larvæ issuing will be found in Tables 8 to 17.

From the detailed records summaries have been made presenting the data in various forms. These are given in Tables 18, 19 and 20.

TABLE 7.

Varieties Used in Securing Records of Period between Fall of Apple and Exit of Larvæ.

Variety.	Season of ripening.	Season of maximum drops in experiments.	Number of drops under observation.
Early Harvest	Late July and Aug.	Late July to mid Aug.	449
Red Astrachan	" " to Sept.	" " " " "	2,396
August Sweet	Aug. and early Sept.	" " " " "	1,729
Sops-of-Wine	Aug. to Oct.	" " " " "	1,624
Porter	Sept. to Nov.	Early Aug. to mid-Sept.	1,938
Gravenstein	Late Sept. to Nov.	" " " "	3,962
Jersey Sweet	Sept. to Dec.	" " " "	2,330
Russet Sweet	Sept. to Nov.	Mid-Aug. to mid-Oct.	1,362
Westfield	Oct. to ——	Sept. and Oct.	1,732
Winter Sweet	Oct. to ——	Sept. and Oct.	2,708
Total			20,230

TABLE 8.

Early Harvest.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
Aug. 7–16	Drops	312	279	245	236	236	236	200
	Larvæ	8	14	19	17	7	13	13
Aug. 11–23	Drops	114	134	158	159	141	124	146
	Larvæ	11	13	4	22	23	33	3
Aug. 18–26	Drops	23	36	46	54	72	89	103
	Larvæ	2	2	1	5	9	2	4

Exit of Larvæ from Drops—after first seven days.

Gathered.	Drops.	Larvæ issuing.		
		2nd wk.	3rd wk.	4th wk.
Aug. 9	63	34	39	2
Aug. 11	36	16	32	7

TABLE 9.

Red Astrachan.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
July 30 to Aug. 5	Drops	725	652	540	389	220	118	118
	Larvæ	0	0	0	2	0	0	3
Aug. 1–12	Drops	684	645	697	746	752	765	737
	Larvæ	1	0	2	0	4	5	6
Aug. 7–19	Drops	647	698	675	732	725	722	620
	Larvæ	0	0	0	1	2	0	2
Aug. 14–26	Drops	312	334	383	395	538	565	647
	Larvæ	1	2	2	0	2	1	4

Exit of Larvæ from Drops—after first seven days.

Gathered	Drops.	Larvæ issuing.										
		2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.	9th wk.	10th wk.	11th wk.	12th wk.
July 30	118	45	69	53								
Aug. 1	102	37	74	55								
Aug. 6	130	33	30	32								
Aug. 8	89	24	13	12								
Aug. 13	66	18	56	35								
Aug. 14	130	40	63	47								
Aug. 16	170	26										
Aug. 20	66	13	6									
Aug. 22	65	0	13									

Table 10.

August Sweet.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
July 30–Aug. 5	Drops	591	487	390	279	189		85
	Larvæ	4	4	2	0	0		1
July 31–Aug. 12	Drops	619	674	711	742	736	726	636
	Larvæ	3	4	6	4	3	8	10
Aug. 7–19	Drops	340	365	414	480	527	595	596
	Larvæ	6	10	17	21	14	15	30
Aug. 14–26	Drops	162	148	133	125	148	178	243
	Larvæ	15	7	4	6	6	19	15
Aug. 21–27	Drops	17	55	81	103	129	146	169
	Larvæ	5	5	10	12	9	13	19

Exit of Larvæ from Drops—after first seven days.

Gathered.	Drops.	Larvæ issuing.										
		2nd wk.	3rd wk.	4th wk.	5th wk.							
July 30	85	187	660	204	10							
Aug. 6	130	186	820									
Aug. 13	107	37	244	174								
Aug. 14	89	20	239	199								
Aug. 20	10	3	25									
Aug. 21	23	6	17									

TABLE 11.

Sops-of-Wine.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
July 30–Aug. 5	Drops	564	464	367	272	128	56	56
	Larvæ	0	0	0	1	0	0	0
Aug. 1–12	Drops	817	872	883	881	789	738	594
	Larvæ	0	1	0	0	3	2	6
Aug. 7–19	Drops	204	240	314	393	578	652	748
	Larvæ	1	4	1	2	5	5	13
Aug. 14–26	Drops	37	34	43	57	101	145	187
	Larvæ	3	2	1	2	2	5	8
Aug. 21–27	Drops	2	14	17	21	28	33	39
	Larvæ	0	4	1	7	7	6	3

Exit of Larvæ from Drops—after first seven days.

Gathered.	Drops.	Larvæ issuing.											
		2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.							
July 30	56	16	72	75	10								
Aug. 1	72	56	228	181	24								
Aug. 2	144	177	502	295	42								
Aug. 6	86	70	384	246									
Aug. 7	144	110	610	75									
Aug. 13	17	22	32										
Aug. 14	48	31	96	55									
Aug. 15	49	59	82										
Aug. 21	6	0											
Aug. 23	7	6											

TABLE 12.

Porter.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
Aug. 18–24	Drops	599	500	397	265	202	119	83
	Larvæ	0	0	0	0	0	0	0
Aug. 19–21	Drops	710	682	652	677	681	702	503
	Larvæ	0	0	0	0	2	4	2
Aug. 26–Sept. 7	Drops	418	518	620	647	624	623	725
	Larvæ	0	0	3	0	1	3	5
Sept. 2–14	Drops	122	133	145	211	271	331	330
	Larvæ	0	0	0	2	2	1	0
Sept. 9–21	Drops	89	105	124	138	160	156	184
	Larvæ	0	0	0	0	0	2	0

Exit of Larvæ from Drops—after first seven days.

Gathered.	Drops.	Larvæ issuing.				
		2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.
Aug. 22	132	23	164	70	7	
Aug. 30	133	62	77	34	10	0
Sept. 5	80	6	62	32	7	
Sept. 12	14	6	5	4	0	

TABLE 13.

Gravenstein.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
Aug. 7–16	Drops	2057	1842	1611	1384	1138	1138	887
	Larvæ	0	0	0	0	0	0	0
Aug. 11–23	Drops	1332	1454	1572	1655	1788	1488	1456
	Larvæ	1	1	0	0	1	1	1
Aug. 18–30	Drops	477	551	642	743	813	1013	1189
	Larvæ	0	0	1	2	0	0	1
Aug. 25–Sept. 7	Drops	96	115	135	160	195	283	383
	Larvæ	0	0	1	1	0	1	3
Sept. 2–6	Drops			2	18	28	38	27
	Larvæ			0	0	0	0	2

Exit of Larvæ from Drops—after first seven days.

Gathered.	Drops.	Larvæ issuing.			
		2nd wk.	3rd wk.	4th wk.	5th wk.
Aug. 10	387	17	504	150	0
Aug. 17	286	10	235	269	9
Aug. 24	143	7	36	109	
Sept. 1	25	1	8		

TABLE 14.

Jersey Sweet.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
Aug. 14–20	Drops	427	358	244	174	151	61	20
	Larvæ	0	0	0	0	0	1	0
Aug. 15–27	Drops	989	988	879	841	740	718	545
	Larvæ	2	0	0	0	0	2	1
Aug. 22–Sept. 3	Drops	429	430	612	647	724	789	896
	Larvæ	1	1	6	0	6	3	16
Aug. 29–Sept. 10	Drops	280	281	277	308	347	378	443
	Larvæ	5	1	2	4	0	6	8
Sept. 5–17	Drops	172	213	250	283	235	228	253
	Larvæ	1	3	3	7	6	7	3
Sept. 12–20	Drops	33	60	68	77	133	156	151
	Larvæ	0	0	0	0	1	0	0

Exit of Larvæ from Drops—after first seven days.

Gathered.	Drops.	Larvæ issuing.										
		2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.	9th wk.			
Aug. 14	20	24	72	82								
Aug. 16	90	84	314	324	156							
Aug. 22	214	157	651	704								
Aug. 29	107	13	64	245								
Sept. 4	59	20	42	91	193	57	9					
Sept. 10	68	17	39	81	60	61	11	5	0			
Sept. 14	56	9	19	42	50	37						

TABLE 15.

Russet Sweet.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
Aug. 18–24	Drops	178	150	112	97	87	57	37
	Larvæ	0	0	0	0	0	1	0
Aug. 19–31	Drops	183	184	211	180	181	198	158
	Larvæ	2	0	0	0	0	0	0
Aug. 26–Sept. 7	Drops	185	186	180	200	178	168	210
	Larvæ	0	0	0	0	0	0	0
Sept. 2–14	Drops	149	157	162	160	172	166	162
	Larvæ	1	0	0	0	0	0	0
Sept. 9–21	Drops	133	129	118	124	138	142	146
	Larvæ	0	0	0	0	0	2	0
Sept. 16–28	Drops	145	141	140	138	127	139	141
	Larvæ	0	0	0	0	0	1	0
Sept. 23 – Oct. 5	Drops	216	225	236	247	211	183	161
	Larvæ	0	0	0	0	0	0	0
Sept. 30 – Oct. 12	Drops	170	168	134	128	159	189	194
	Larvæ	0	0	0	0	0	0	0
Oct. 7–13	Drops	3	22	69	86	109	118	152
	Larvæ	0	0	0	0	0	0	1

Exit of Larvæ from Drops—after first seven days.

Gathered.	Drops.	Larvæ issuing.										
		2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.	9th wk.	10th wk.	11th wk.	
Aug. 18	37	0	1	1	3	3						
Aug. 25	17	0	2	0	12	5	2					
Sept. 1	44	0	2	6	13	17	0	1	0	0	1	
Sept. 8	21	6	0	0	9	6	2	2	0	0		
Sept. 15	18	0	1	3	5	3	1	0	0	0	0	
Sept. 22	26	0	0	6	6	4	0	0	0	0		
Sept. 29	42	0	0	0	0	1	0	0	0	0		
Oct. 6	21	0	0	0	0	0	0	1				
Oct. 11	47	0	0	0	0	0	0					

TABLE 16.

Westfield.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
Aug. 26–Sept. 1	Drops	99	70	70	62	46	37	22
	Larvæ.	0	0	0	1	1	2	0
Aug. 27–Sept. 8	Drops	93	110	102	97	93	86	89
	Larvæ	1	0	0	1	0	0	0
Sept. 3–15	Drops	209	189	158	141	125	106	97
	Larvæ	1	0	0	0	0	1	0
Sept. 10–22	Drops	193	207	226	243	246	254	235
	Larvæ	0	0	0	0	0	0	0
Sept. 17–29	Drops	168	153	142	133	145	154	174
	Larvæ	0	0	0	0	0	0	0
Sept. 24–Oct. 6	Drops	387	352	308	253	237	185	190
	Larvæ	0	1	0	0	0	2	2
Oct. 1–13	Drops	236	287	312	341	361	406	393
	Larvæ	0	1	0	0	0	1	0
Oct. 8–20	Drops	252	203	213	222	231	196	196
	Larvæ	0	1	0	0	0	1	0
Oct. 15–22	Drops	95	161	197	240	248	300	288
	Larvæ	0	1	0	0	0	1	0

Exit of Larvæ from Drops—after first seven days.

Gathered.	Drops.	Larvæ issuing.										
		2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.	9th wk.	10th wk.	11th wk.	12th wk.
Aug. 26	22	0	2	8	21	3	0	0	0	0	0	0
Sept. 2	12	0	1	10	13	1	3	1	0	0	0	0
Sept. 9	16	0	0	13	12	12	1	0	0	0	0	
Sept. 16	42	0	12	28	40	5	0	0	0	0		
Sept. 23	23	3	11	7	11	0	1	0	0			
Sept. 30	45	5	8	15	15	2	0	0				
Oct. 7	51	0	4	2	0	2	0					
Oct. 14	11	0	0									
Oct. 22	48	0	3	0	0							

TABLE 17.

Winter Sweet.

Exit of Larvæ from Drops—first seven days.

Gathered.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
July 30–Aug. 5	Drops	24	24	14	14	9	9	9
	Larvæ	0	0	0	0	0	0	0
July 31–Aug. 12	Drops	30	28	33	33	35	33	30
	Larvæ	3	0	0	0	0	0	0
Aug. 7–19	Drops	68	36	35	29	25	24	19
	Larvæ	0	0	0	0	0	0	0
Aug. 14–26	Drops	188	174	126	107	93	71	64
	Larvæ	0	1	0	0	0	0	0
Aug. 21–Sept. 2	Drops	271	295	293	272	261	253	236
	Larvæ	0	0	0	0	0	0	0
Aug. 28–Sept. 9	Drops	545	428	401	390	375	303	253
	Larvæ	0	0	0	0	0	0	2
Sept. 4–16	Drops	316	443	492	493	511	578	591
	Larvæ	0	0	0	0	0	0	0
Sept. 11–24	Drops	196	189	201	243	259	264	273
	Larvæ	0	0	0	0	0	0	0
Sept. 19–30	Drops	226	238	202	157	129	135	163
	Larvæ	0	0	0	0	0	0	0
Sept. 25–Oct. 7	Drops	500	455	415	416	392	359	284
	Larvæ	0	0	0	0	0	0	0
Oct. 2–14	Drops	338	370	421	428	458	451	496
	Larvæ	0	0	0	0	0	0	0
Oct. 9–21	Drops	6	28	75	126	161	228	290
	Larvæ	0	0	0	0	0	0	0

Exit of Larvæ from Drops—after first seven days.

Gathered.	Drops.	Larvæ issuing.										
		2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.	9th wk.	10th wk.	11th wk.	12th wk.
July 31	9	0	0	0	0	1						
Aug. 6	16	0	0	0	1							
Aug. 14	8	0	2	0								
Aug. 19	34	0	0	1	0	7	5	10	10	3	0	0*
Aug. 25	54	0	0	2	0	1	5	13	11	3	6	0†
Sept. 4	39	1	1	0	0	1	4	5	5	0	0	0
Sept. 10	26	0	1	0	0	2	2	0	4	0	0	
Sept. 14	56	0	0	0	0	2	5	5	3	0	0	
Sept. 19	60	0	0	0	0	0	1	1	1	0		
Sept. 25	32	0	0	0	0	0	1	0	0			
Oct. 1	58	0	0	0	0	0	0	0				
Oct. 8	54	0	0	0	1	0	0					

* Carried out to fourteenth week inclusive.
† Carried out to thirteenth week inclusive.

TABLE 18.

Influence of Variety on Rate of Exit of Larvæ.

Number of Larvæ per 1,000 Drops—first seven days. (Season Totals.)

	1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	5th 24 hrs.	6th 24 hrs.	7th 24 hrs.
Early Harvest	46	64	53	98	86	106	44
Red Astrachan	.8	2.5	3.7	5.4	8	5.5	9
August Sweet	18	17	22	25	18	31	43
Sops-of-Wine	2	6	3	8	11	11	18
Porter	0	0	1.5	1	2	5	3
Gravenstein	.2	.2	.5	.7	.2	.5	1.3
Jersey Sweet	4.	2	2	5	6	8	12
Russet Sweet	4	0	0	0	0	2	0
Westfield	1	2	0	1	.5	4.6	1
Winter Sweet	1	.3	0	0	0	0	.7

Number of Larvæ per 1,000 Drops—entire period. (Season Totals.)

	Total 1st wk.	2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.	9th wk.	10th wk.
Early Harvest	479.	505	717	90						
Red Astrachan	34.9	230	330	240						
August Sweet	174.	988	4,515	1,299	22					
Sops-of-Wine	59.	710	3,189	1,473	120					
Porter	12.5	242	579	392	67					
Gravenstein	3.6	41	931	746	10					
Jersey Sweet	39.	527	1,957	2,555	747	252	32	8		
Russet Sweet	6.	22	22	58	175	142	17	14		
Westfield	9.6	29	151	307	451	92	18	4		
Winter Sweet	2.	1	7	5	5	33	46	78	74	19

TABLE 19.

Influence of Time of Dropping on Rate of Exit of Larvæ.

Number of Larvæ per 1,000 Drops—first week after apple falls.

Early Harvest	Date dropped	Aug. 11	Aug. 17	Aug. 22							
	Larvæ per M	371	712	416							
Red Astrachan	Date dropped	Aug. 2	Aug. 6	Aug. 13	Aug. 20	Aug. 25					
	Larvæ per M	12	29	7	26	290					
August Sweet.	Date dropped	Aug. 2	Aug. 6	Aug. 13	Aug. 20	Aug. 25					
	Larvæ per M	38	56	238	444	730					
Sops-of-Wine .	Date dropped	Aug. 2	Aug. 6	Aug. 13	Aug. 20	Aug. 25					
	Larvæ per M	3	15	64	267	400					
Porter	Date dropped	Aug. 21	Aug. 25	Sept. 1	Sept. 8	Sept. 15					
	Larvæ per M	0	10	20	22	14					
Gravenstein ..	Date dropped	Aug. 11	Aug. 17	Aug. 24	Aug. 31	Sept. 4	Sept. 18				
	Larvæ per M	0	3	5	30	125	10				
Jersey Sweet .	Date dropped	Aug. 17	Aug. 21	Aug. 28	Sept. 4	Sept. 11					
	Larvæ per M	5	6	51	79	129					
Russet Sweet	Date dropped	Aug. 21	Aug. 25	Sept. 1	Sept. 8	Sept. 15	Sept. 22	Sept. 29	Oct. 6	Oct. 9	
	Larvæ per M	9	10	0	6	15	7	0	0	5	
Westfield	Date dropped	Aug. 29	Sept. 2	Sept. 9	Sept. 16	Sept. 23	Sept. 30	Oct. 7	Oct. 14	Oct. 18	
	Larvæ per M	34	21	13	0	0	18	6	9	9	
Winter Sweet.	Date dropped	Aug. 2	Aug. 6	Aug. 13	Aug. 20	Aug. 27	Sept. 3	Sept. 10	Sept. 17	Sept. 25	
	Larvæ per M	0	90	0	8	0	6	0	0	0*	

* Continued to October 21. No further larvæ issued during first week.

TABLE 20.

Influence of Time of Dropping on Total Number of Larvæ Issuing.

Number of Larvæ per 1,000 Drops—during entire period after apple falls.

Early Harvest	Date dropped	Aug. 9	Aug. 11									
	Larvæ per M	1561	1,891									
Red Astrachan	Date dropped	July 30	Aug. 6	Aug. 13	Aug. 16	Aug. 20	Aug. 22					
	Larvæ per M	1,512	759	1,657	176	315	229					
August Sweet	Date dropped	July 30	Aug. 6	Aug. 13	Aug. 20	Aug. 21						
	Larvæ per M	12,438	7,756	4,438	3,244	1,444						
Sops-of-Wine	Date dropped	July 30	Aug. 2	Aug. 6	Aug. 13	Aug. 15						
	Larvæ per M	3,093	7,053	8,115	3,164	2,864						
Porter	Date dropped	Aug. 22	Aug. 30	Sept. 5	Sept. 12							
	Larvæ per M	2,010	1,395	1,922	1,085							
Gravenstein	Date dropped	Aug. 10	Aug. 17	Aug. 24	Sept. 1							
	Larvæ per M	1,737	1,831	1,067	390							
Jersey Sweet	Date dropped	Aug. 14	Aug. 16	Aug. 22	Aug. 29	Sept. 4	Sept. 10	Sept. 14				
	Larvæ per M	8,905	9,760	7,015	3,060	7,062	4,158	2,932				
Russet Sweet	Date dropped	Aug. 18	Aug. 25	Sept. 1	Sept. 8	Sept. 15	Sept. 22	Sept. 29	Oct. 6	Oct. 11		
	Larvæ per M	225	1,245	909	1,196	737	622	23	47	5		
Westfield	Date dropped	Aug. 26	Sept. 2	Sept. 9	Sept. 16	Sept. 23	Sept. 30	Oct. 7	Oct. 14	Oct. 22		
	Larvæ per M	1,579	2,437	2,388	2,023	1,434	1,018	162	9	71		
Winter Sweet	Date dropped	July 31	Aug. 6	Aug. 14	Aug. 19	Aug. 25	Sept. 4	Sept. 10	Sept. 14	Sept. 25	Oct. 1	Oct. 8
	Larvæ per M	110	150	250	1,058	760	436	340	260	31	0	18

INFLUENCE OF VARIETY ON RATE OF EXIT OF LARVÆ.

It is clear that the variety of apple, as indicating its season of ripening and characteristics of flesh, is of vital influence on the time required for the larvæ to mature and issue from the drops.

If the fruit is of an extreme early type, growing mellow on the tree and dropping in midsummer, exit of the larvæ begins quickly and proceeds rapidly. A fourth of the larvæ may issue by the close of the first week. Taking Early Harvest as a type of this extreme, the issuance from drops in 1910 in the first week after the apple fell amounted to 27.4 per cent of the total. Exit of larvæ came to an end after drops had been off the tree four weeks. The maximum issuance occurred the third week.

A slightly increased firmness of pulp, even in early fruit, results in a much less rapid rate of issuance the first week. Thus with Red Astrachan, August Sweet and Sops-of-Wine in 1910, 4.2 per cent, 2.5 per cent and 1 per cent, respectively, of the total larvæ issued the first week. The period required for exit of all larvæ was about four weeks. The maximum was reached the third week.

The typical fall apples, such as the Porter, Jersey Sweet or Russet Sweet, show a limited exit of larvæ during the first week, the percentages being respectively 1 per cent, .6 per cent, and 1.3 per cent. In the second week, if the fruit is of quality that tends to mellow rapidly, as with the Porter, issuance may reach a more rapid rate, passing on to a maximum in the third week. If the fruit is of firmer characteristics the process is slower, and maximum issuance may not occur until the fourth or fifth week.

With winter fruit the length of time before any considerable exit takes place is greatly prolonged. With Winter Sweet it was found that during the first five weeks exceedingly few larvæ issued, although the fruit showed many egg punctures. Issuance then became somewhat more rapid, reaching a maximum the eighth and ninth weeks, but at no time did larvæ issue in numbers commensurate with the number of egg punctures.

INFLUENCE OF TIME OF DROPPING ON EXIT OF LARVÆ.

The time when drops fall, whether early or late in the season, has with some varieties a clear influence on the rate of exit of the larvæ; and similarly there is with certain types of fruit a marked influence on the total number of larvæ issuing.

An examination of Table 19 will show that with ordinary summer or fall fruit the larvæ issue more quickly from drops that fall toward the close of the season than from those that fall early. With Early Harvest this is not evident, presumably because this fruit, in this experiment at least, mellowed to a marked degree while still on the tree. With Red Astrachan, August Sweet and others, many more larvæ issued the first week toward the end of the season than at the beginning.

With winter fruit there is apparently little difference in this regard between drops falling early and those falling late.

Table 20, which shows the total number of larvæ issuing from early drops as compared with those from late drops of the same variety, gives another aspect of the case. Here we find that usually the earlier drops, especially those of August, if allowed to lie undisturbed, give the maximum total larvæ. If the variety is such that the season of dropping extends into fall there is a marked diminution in the total number of larvæ issuing.

Winter apples falling after the third or fourth week in Septem-

ber mature comparatively few larvæ, although as shown in other records these drops may show large numbers of egg punctures. In other words such drops probably do not mellow up sufficiently before cold or freezing weather to provide suitable conditions for the larvæ in them to reach full growth.

The detailed records from which these conclusions are drawn and the manner in which the experiments were carried out are given in Table 7, p. 62.

Experiments in 1910. For the study of the period between the fall of the apple and the exit of larvæ 10 varieties of apples were selected, representing summer, early fall, late fall, and winter fruit. The varieties chosen, their period of ripening, and the number of drops observed in the experiments are given in the table below.

With some of the varieties several trees were used in the experiments. These trees were located in part at Durham, in part at Beauty Hill.

With each variety the work of recording the drops was begun as soon as the apples had begun to fall in any numbers. The records were continued as long as fruit continued to fall, and were maintained with typical lots until the last fruit of each variety had rotted, or until the ground was frozen and all issuance of larvæ had ceased.

Under each tree the ground was cleared of any drops at the beginning of the records. Each day thereafter all drops were collected.

A series of boxes was prepared for each variety. Soil was placed in the bottom of each box. With each variety the procedure was then as follows:

The drops of a given day were placed for the first twenty-four hours in Box No. 1; for the second twenty-four hours in Box No. 2, and so on for first seven consecutive days. Each day, as the drops from Box 1 were moved to Box 2 their place was taken by the apples collected that day. As the drops in Box 2 were moved forward to Box 3, their place was taken by the drops that had been in Box 1 for the preceding twenty-four hours. And so on for each of the boxes. Thus Box 1 represented the first twenty-four hours after the apple fell; Box 2 the second twenty-four hours, and so on. At the end of each week the dirt in each box was sifted and the pupæ in it removed and recorded.

At the end of each seven days or oftener, a typical lot of apples was chosen for further record, the other lots of that period now being discarded at the close of their seven-day records. The selected lots were now run through a series of similar boxes in which they remained on soil for one-week periods throughout the remainder of the experiments with that variety. The soil in these boxes was sifted for pupæ once a week.

Thus the records obtained show, for each variety, the actual emergence of larvæ each day for the first seven days and the emergence weekly thereafter for typical lots; and in addition this record is distinct for the drops of each week from the time when the apples began to fall until the end of the season.

The detailed results of the experiments are given in Tables 8 to 17, inclusive. Summaries from these tables are presented in Tables 18, 19 and 20.

LARVÆ ISSUING FROM LATE APPLES REMOVED FROM NORMAL CONDITIONS.

It has frequently been observed that larvæ may issue in numbers from apples of later varieties while such fruit is being held awaiting barreling or storage, especially if subjected to comparatively high temperatures. Apparently the condition is simply that the fruit is thereby permitted to mellow sufficiently for the maturity of the larvæ, a circumstance that may not come about when such fruit remains on soil in the open.

In 1909, between September 18 and October 13, various small lots of infested fall and winter fruit were brought to Durham. Some apples from each lot were placed in an incubator maintained at a temperature of approximately 80 degrees, F., while others were placed on soil outdoors. The lots were too small to permit of general conclusions, but with late fruit it was noted that larvæ matured and issued in some numbers from lots in the incubator, while from corresponding lots in the open few or no larvæ issued.

MORTALITY OF COMBINED EGG AND LARVAL STAGES.

The total mortality of this species in the egg and larval stages is often high and, with late drops of hard, winter varieties, may reach 100 per cent. The soft fruit, falling early, furnishes the

most favorable conditions for these stages; but even here the proportion of mature larvæ to egg punctures may be only as 1 to 2 or 1 to 3.

In the course of the experiments of 1910 and 1911 various lots of apples were examined carefully for egg punctures, and the totals recorded. The count of egg punctures was not verified by examination of the pulp for the egg; it cannot be said, therefore, that each puncture noted represented a fertile egg. The number of larvæ issuing is nevertheless interesting. These data are given in Table 21. It will be seen that the apparent mortality of the combined egg and larval stages, assuming that egg punctures represent fertile eggs, ranges from 14.6 per cent, the lowest, to 100 per cent. The average for all the lots is 64.2 per cent.

The Winter Sweets recorded in Table 17 were rather badly infested. Others of the same variety, from the same neighborhood, and growing under similar conditions, gave a count showing 10,523 punctures to 1,538 apples, an average of 6.7 per apple. The number of larvæ issuing from the 511 specimens recorded in Table 17 was .281 per apple.

Various lots of Early Harvests were under observation in July and August, 1911, the egg punctures being counted and the larvæ issuing recorded. The apparent mortality ranged from 20 to 68.6 per cent, with an average of 53.7 per cent.

Similar results are apparent in experiments of others. Illingworth (34, p. 139) states that 300 Tolman Sweets and 100 Northern Spies were placed on soil in the open September 28. From these only 3 adults emerged the following season. The probability appears to the writer to be that very few larvæ issued from the apples placed in the open thus late in the season. It is stated that other apples from the same lots placed in the glass insectary gave an average of over three larvæ per apple.

Ross (55), in experiments with four varieties including summer, autumn, early winter and late winter, found a mortality of combined egg and larval stages ranging from 77 to 98.7 per cent.

TABLE 21.

Ratio of Egg Punctures to Number of Larvæ Issuing.

Variety.	Date gathered.	Drops or picked.	No. apples.	No. egg punctures.	No. larvæ.	Apparent per cent mortality.
Red Astrachan	July 29, 1911	Drops	67	32	5	84.3
August Sweet .	25,	"	61	38	16	57.9
	30,	"	71	42	13	69.0
	Aug. 10,	Picked	495	1,069	535	49.9
Sops-of-Wine..	July 25,	Drops	157	115	34	70.5
	30,	"	183	67	47	29.8
	Aug. 10,	"	279	378	302	20.1
Porter.....	19,	"	40	41	11	73.1
	23,	"	91	85	45	47.0
	Sept. 1,	"	52	43	10	76.7
	14, 1910	"	112	275	30	89.1
Jersey Sweet .	July 25, 1911	"	70	85	23	72.9
	Oct. 1,	"	108	1,112	0	100.0
Russet Sweet .	Aug. 24,	"	84	42	17	59.5
Granite Beauty	July 25,	"	379	224	3	98.6
	25,	"	362	222	0	100.0
	Aug. 16,	"	378	436	372	14.6
	Oct. 5,	"	198	116	1	99.1
Roxbury Russet	Aug. 25, 1910	"	378	3,010	1,692	43.8
	Sept. 24,	"	279	2,632	657	75.0
Tolman Sweet.	9,	"	250	1,554	346	77.8
Totals....				11,618	4,159	64.2

Mortality of Egg and Larval Stages when Drops are Exposed to Sun. No apparent unfavorable effects were observed when drops were exposed to direct sunlight, as compared to drops in shade. The number of larvæ issuing in the tests varied, but not in such manner as to indicate relationship. Thus, two lots of Porters, each lot with 100 egg punctures, were used in one experiment, one lot being in sun and the other in shade. From the first 67 larvæ issued; from the second 94. Again, two lots of Tolman Sweets were used in similar experiment. In this case each lot consisted of 125 apples, and each lot showed a total of 777 punctures. From those in sun 207 larvæ issued; from those in shade 139.

EXIT OF LARVÆ BY DAY COMPARED WITH NIGHT.

In experiments in 1910 more larvæ issued from apples during the hours of 6 p. m. to 6 a. m. than issued in the other half of the twenty-four hours. The difference was marked. Table 22 summarizes the results.

TABLE 22.

Exit of Larvæ in Daytime Compared with Night.

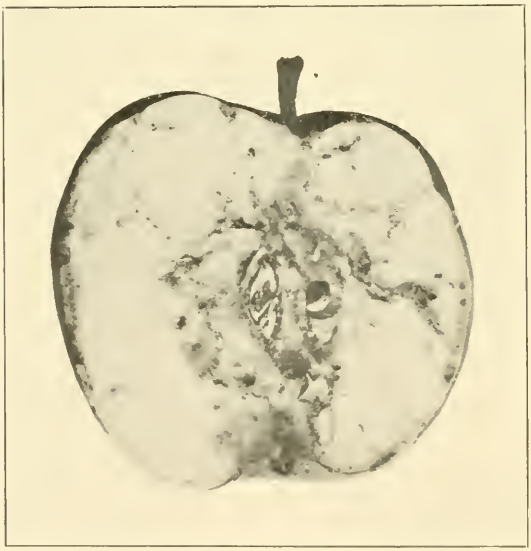
Description of lot.	Dates examined.		Time a. m.	No. larvæ issued.	Time p. m.	No. larvæ issued.
75	Aug.	22			4:50	0
August Sweets.		23	8:00	34	4:45	6
		24	8:00	33	4:50	7
		25	8:00	60	5:45	10
		26	8:00	64	4:50	6
		27	8:00	61		
Total time, night, 75 hrs. Total larvæ, 252. Total time, day, 36 hrs. Total larvæ, 29.						
Ratio, night issuance to day issuance, 4.2 to 1.						
110	Sept.	15	6:00	2	6:00	8
Jersey Sweets.		16	6:00	4	6:00	0
		17	6:00	7	6:00	0
		18	6:00	7	6:00	6
		19	6:00	12	6:00	4
		20	6:00	16	6:00	13
		21	6:00	12	6:00	6
		22	6:00	20	6:00	3
		23	6:30	53	7:30	2
		24	6:00	16	6:00	13
		25	6:00	22	6:00	17
		26	....	21	....	10
		27	....	38	....	8
		28	....	42	....	25
		29	6:50	34	8:00	16
		30	7:15	28	7:30	4
	Oct.	1	6:00	11	9:10	3
		2	8:50	8	9:30	0
		3	7:20	22	8:30	3
		4	7:30	17	6:45	4
		5	6:50	4	6:40	0
Total time, night, 249 hrs. Total larvæ, 396. Total time, day, 255 hrs. Total larvæ, 144.						
Ratio, night issuance to day issuance, 2.8 to 1.						

PLATE I.

BURROWS OF LARVAE SHOWING THROUGH SKIN OF LIGHT-COLORED FRUIT.

BURROWS OF LARVAE IN FRUIT OF FIRM FLESH. EXIT TUNNEL OF LARVA SHOWING IN UPPER PART OF APPLE.

PLATE II.



BURROWS OF LARVAE IN FRUIT OF SOFT TEXTURE.

PLATE III.

ADULT FEMALE—NATURAL SIZE.

EGG PUNCTURES IN APPLE OF LIGHT-COLORED SKIN.

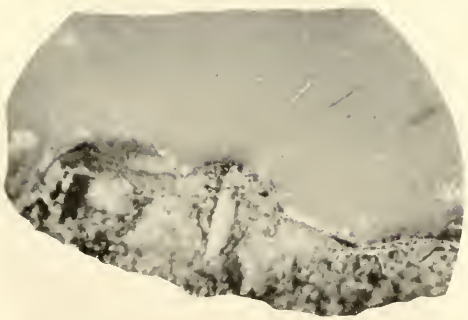
PLATE IV.

ADULT MALE—ENLARGED.

ADULT FEMALE—ENLARGED.

PLATE V.

OVIPOSITOR EXTENDED—MUCH ENLARGED.



EGG INSERTED IN FRUIT—ENLARGED.

PLATE VI.

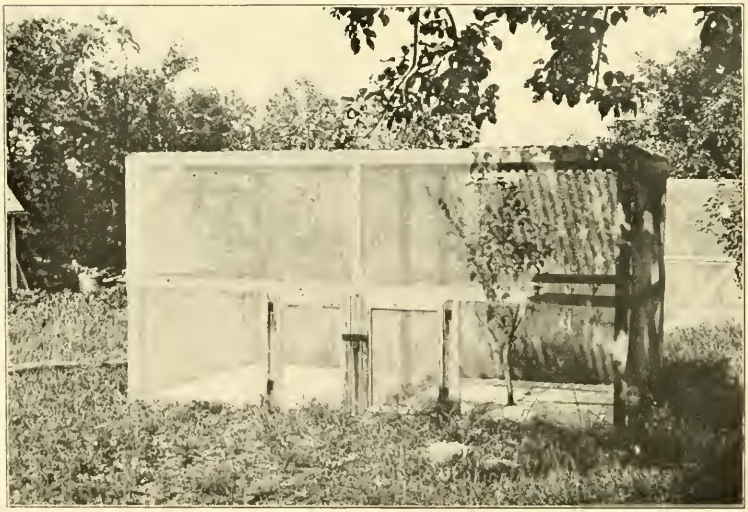
LARVA ISSUING FROM FRUIT—PHOTOGRAPHED FROM LIFE—SLIGHTLY ENLARGED.

EXIT HOLES OF LARVAE.

LARVA IN FLESH OF APPLE—ANTERIOR SEGMENTS RETRACTED—ENLARGED.

PUPARIA—ADULT EMERGING FROM SPECIMEN AT LEFT—ENLARGED.

GROUND CAGES IN WHICH ADULTS OF THE TWO-YEAR LIFE CYCLE WERE REARED.



TYPE OF TREE CAGES USED IN STUDIES OF ADULTS.

DURATION OF THE LARVAL STAGE.

It is clear from much data already noted that the duration of the larval stage with this species is variable, being influenced materially by the variety of apple in which the larva is at work, the condition of the fruit, the time of season, and probably other factors.

That the larval stage may on occasion be completed in normal surroundings in not to exceed thirty days is suggested by the following:

In 1911 the date of first emergence of adults recorded at Durham was June 26. The first larva recordes from apples collected at Durham issued August 4. Assuming four days as the minimum period after emergence of the adult before egg-laying can begin, and five days as the duration of the egg stage, the length of the larval period would be not to exceed thirty days. That it may be less is obvious. Also it is certain that with hard, winter fruit the stage may last for many weeks longer.

Harvey (25, p. 202) found newly hatched larvæ about July 10 in Early Harvests, and found the maggots maturing August 10.

EXIT OF LARVA FROM FRUIT.

When growth is completed the larva normally leaves the fruit to prepare for pupation. As already noted this takes place after the fruit has fallen from the tree. A somewhat irregular hole is made through the skin of the apple, and the larva squeezes through this. The hole is not made very large. Occasionally larvæ start to force the body through and when half-way out are unable to get farther. Usually the process of issuance is rapidly accomplished. If the larva has not come out at a point near to or in contact with the soil it makes its way over the surface of the fruit, to which it seems able to cling fairly well.

After issuing the larva may crawl about on the surface of the soil for some time before entering it. This seemed especially true if the apple from which the larva had issued was removed. Under these conditions larvæ were found still uncontracted and on the surface of the ground after nine hours. In one instance the apple was replaced after eight and a half hours, and two larvæ that had issued from it at once made their way toward it and in half an hour disappeared.

Pupation sometimes takes place inside the fruit. Illingworth (34, p. 146) found this especially the case where the fruit was attacked by black-rot.

DEPTH LARVÆ PENETRATE INTO THE SOIL.

Examination of sod beneath infested trees showed pupæ present not far from the surface of the soil, among the upper grass roots. Examination of cultivated ground disclosed pupæ in greatest abundance at depths of one to two inches, though much depends on the character of the soil.

In 1908 infested apples of four varieties were placed on sandy soil and allowed to rot. This soil was carefully examined the following spring and pupæ were found at the depths given in Table 23.

TABLE 23.

Depths at which Pupæ Were Found in Sandy Soil.

Variety of fruit.	Date placed on soil.	Pupæ found at following depths in inches:									
		½″	1″	1½″	2″	2½″	3″	3½″	4″	4½″	5″
Russet Sweet ...	Sept. 28	5	15	23	21	5	3	2	0	0	0
St. Lawrence ...	30	2	3	7	6	3	3	4	2	1	0
Grimes Golden	28	5	13	32	28	9	13	2	1	6	2
Unknown	..	2	4	7	5	5	1	2	1	1	0
Total.....		14	35	69	60	22	20	10	4	8	2
Percent of total.....		5.7	14.3	28.3	24.8	9.0	8.2	4.1	1.6	3.2	.1

Proportion found at depths 1½ to 2 inches, 52.9 per cent.
Proportion found at depths 1 to 3 inches, 84.4 per cent.

DATES OF FIRST AND LAST PUPATION.

The dates of first and last pupation cover a wide range of time, probably extending through about four months. In the latter half of this period, however, the proportion of individuals entering the pupal stage rapidly diminishes.

In the records of this investigation the earliest date of formation of the puparium in the open under normal surroundings was August 3, 1910. Quite likely in favorable seasons some larvæ

may transform several days earlier than this. The latest date was November 27, 1909, the variety of apple being Gilliflower.

The majority of individuals pupate in July, August and the early part of September, in the latitude of southern New Hampshire.

DURATION OF THE PUPAL STAGE.

The length of the pupal stage is variable between wide limits. As will be described later, a point of separation between individuals occurs at this stage in the life history. A proportion of individuals complete the pupal stage in approximately 300 days, giving the one-year life cycle hitherto considered characteristic of the species. Another proportion may remain in the pupal stage for an extra twelve months, giving a two-year life cycle. The data on which these findings are based will be found in detail below.

ONE-YEAR LIFE CYCLE.

The duration of the pupal stage, in the case of individuals that complete their life round in one year, apparently approximates 300 days, but may vary thirty days or more in either direction from this figure. General conclusions are not possible from the records in hand as to an average or the extremes. The minimum pupal stage observed was 272 days, and the maximum 339 days. With pupation occurring actively throughout two months and to some extent through two more, and with emergence of adults actively in progress for about one month, there is evident ground for a varying duration of this stage.

Records of the duration of the pupal stage with individuals of the one-year cycle will be found below in Table 24.

Observations were not forthcoming to show that pupæ from late maturing larvæ necessarily transform late the following season. On occasion at least they may transform early. Among the early emerging flies noted were some from comparatively late pupæ.

However, in other instances, it was observed that the emergence of adults from pupæ that had their origin in very early fruit clearly began early and reached a maximum somewhat early in the season. In Table 4 it will be noted that the records of emergence in the first and third columns are from early apples in which pupation was occurring early in the season. The records in the

second column are from fall apples in which pupation was taking place about a month later than with the other two lots. The emergence records show a difference of about a week in the maximum emergence between the early and the later pupæ. Similarly, in 1910, in the case of pupæ from August Sweets and Sops-of-Wine, emergence began distinctly early and seemed to reach an early maximum, being at an end while emergence was still in progress from later pupæ. The data are not sufficient for drawing definite conclusions. Various other features, such as the kind of soil, the location of the pupæ with reference to shade, and the local conditions of moisture, probably have much influence.

TWO-YEAR LIFE CYCLE.

That a proportion of individuals of the Apple Maggot may require two years instead of one to complete the life cycle was discovered in certain records made in 1913.

In prior experiments it had been found that with many lots of pupæ only partial emergence occurred the summer following pupation.

In 1911 4 lots of infested apples were placed in 4 of the concrete bins in the open-air work-room of the insectary. These bins contain soil continuous with the earth beneath. The soil tends to dry out somewhat in the surface layers, but is kept more moist when covered with a layer of apples. In 1912 there was ordinary emergence of adults. The contents of the bins remained unchanged. In 1913 each bin was covered with a screen-wire cage. On July 11 adults began to emerge, and emergence continued to July 29, inclusive, 138 adults being secured. The detailed emergence records will be found below in Table 25.

In three of the bins the apples were a fall variety. These were collected September 1 in one case and September 11 in the other two. The latter were placed in the bins September 15. The remaining lot was an early variety, picked August 10 and placed in the bin August 11.

Further data secured in 1912 to 1914 are as follows. In 1912 three lots of infested apples were brought to Durham and piled on sod. Lot No. 1 consisted of three fourths bushel of August Sweets, and was placed beneath a small linden tree. Lot No. 2

consisted of three fourths bushel of Porters and was placed under a linden tree. Lot No. 3, consisted of three fourths bushel of Early Harvests, and was placed under an ash tree. Each lot was covered with a screen-wire cage, which was kept thereafter in position. In the summer of 1913 adults emerged at the ordinary time in each of the cages. The detailed emergence records are given in Table 4, columns 1, 2 and 3. The adults were removed as found. Soil and cages were left unchanged. In April, 1914, a small section of earth from each cage was removed and examined. Considerable numbers of pupæ were found.

As the season progressed adults emerged from these pupæ and in the cages in the open. From Lot No. 1 a total of 7 adults were secured; from Lot No. 2, 10 adults; and from Lot No. 3, 12 adults; all of these, of course, representing the two-year life cycle. It will be noted that with two of these lots the fruit was of early variety, and had contained early maturing larvæ. It had been collected, in fact, to obtain evidence as to the existence or non-existence of a second brood the same season of ripening.

RESISTANCE OF PUPÆ.

With this species as with many others, the pupa, once successfully formed, is measurably resistant to unfavorable surroundings. Since pupæ normally occur in nature within two or three inches of the surface of the ground and remain successfully there throughout fall, winter and spring, it is obvious that they are able to withstand extremes of heat, cold and moisture in varying combinations.

Newly emerged larvæ placed on dry soil on which there are no fallen apples exhibit what may be assumed to be signs of discomfort. Illingworth (34 p. 162) found that individuals forming the puparium under such conditions, may fail to enter the pupal stage successfully. In nature, however, the issuing larva has access to soil immediately beneath the fallen fruit from which it came. Some moisture, as well as other favorable conditions, is certain to prevail in such situation. The circumstances do not appear to the writer comparable.

On occasion, at least, pupæ in barrels or boxes in which apples have been allowed to decay may withstand such surroundings successfully. In 1910, at Durham, adults emerged from pupæ in conditions of this nature.

TABLE 24.

Duration of Pupal Stage—One-Year Life Cycle.

Variety of Apple.	Date of pupation.	June.				July.															Emergence dates.																		August										Duration—days.		
		27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	15	20	Min.	Max.	Mean.
Gravenstein ..	Sept. 8-15							2	1			3		2				2			1	1	3	2		2			2																				
Jersey Sweet ..	12		1	1	1	1		2	4			3				1		1			2	1	1																								289	310	299
"	15																			1		1		1																								303	308	305
"	17																					1	1																								303	305	304
"	6-20												3									1			1																								
"	22				1							1									1	1							1					1												281	313	297
"	23				1												1	2			1			2		2	1		1																280	305	299
"	24										1									1					1																						285	300	292
"	25												1																1	1																	287	305	295
"	26								1			1	2	2			1			1	1																									283	295	289
"	27							1		2	2		1					1			4	1	4				2	1			1				1										279	308	293
"	28												1												1																					282	296	289
Russet.....	16												1								1			1																					293	305	299
"	19															1														1																295	310	302
"	23																											1	2						1											304	312	308
"	24																						1								1															296	305	300
"	24																				2		2	3			4	1	2					5	8										294	310	302
Baldwin	Oct. 6-14		1																																1												
"	14-31																						2				1		1					1													
Porter.....	Aug. 20-Nov. 30				3		4	7	11	15	7	2	9	8	6	1	20		18	19	21	17	36	36	30	29	17	54	21	1	6	3	19	25	17	19		4	10	5	8	6	2	2	2			
"	Sept. 14-Nov. 14											1								1											1																	
Tolman Sweet	Sept. 16-Dec. 1						1										1					1				3		1	1																		
"	Sept. 16-Dec. 2		1									2	1	2	1						3		1		1		1	4		2			1													

TABLE 25.

Emergence of Adults in 1913—Two-Year Life Cycle.

Variety.	Date fruit collected.		Emergence of adults—month of July.																				
			11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27	28	29	Total
Jersey Sweet picked	Sept. 11, 1911	Males							1	1	2		2	1		1				1	9
		Females				1		3	1	1	1		1	1	1	1	2	1	1	1	16
Jersey Sweet drops	Sept. 11, 1911	Males	1	1		1	5	2	5	1	8		8	4	2	2	1	1	1	1	44
		Females	2	3		1	3	2	7	1	2	5	5	1		2	3	1	3	2	44
Jersey Sweet drops	Sept. 1, 1911	Males					1	1	1				2								5
		Females			1		2					2	1		1		1				8
Sops-of-Wine picked	Aug. 10, 1911	Males				1	1					1		1							4
		Females					2	1		1		1	1	1			1				8
Totals			3	4	1	4	14	9	15	5	13	9	20	9	4	6	8	3	5	5	138

DESCRIPTION OF STAGES.

In an extended account of this species Harvey (25 p. 215) published careful technical descriptions of the various stages. Illingworth also (34 p. 151) gave complete and detailed descriptions.

The following is condensed from the above.

Adult Female. Color black, marked with white; length 6 mm.; spread of wings 12 mm.

Head.—Light brown, fading to pale yellow on lower face; hind margin of eye white. Frontal bristles black, except a small yellowish pair behind the ocelli. Eye green, with bluish or brown reflections. Antenna orange; length, .5 mm.; 3-jointed, with slender, 2-jointed arista. First segment of antenna with black hairs on distal front margin, second segment with black hairs on inner face and outer distal margin, third segment pubescent. Mouth broad; proboscis and palpi light yellow; palpi short.

Thorax—Black, with white stripe on each side from humeral callus to base of wing. Four gray, longitudinal stripes on dorsum; arranged in pairs, separated by broad, median space; outer stripe of each pair the longer; the stripes of each pair confluent in front. Scutellum elevated, white above, the base and sides black.

Legs—Front pair shortest, length 3.8 mm.; middle pair longest, length 4.5 mm. Femora and tibiæ equal, tarsi a little shorter. Femora black at middle, lighter toward ends. Tibiæ yellow. Tarsi with proximal joints yellow, distal joints covered with black hairs.

Wings—Length 5 mm., width 2.25 mm. Hyaline, crossed with four dark bands. The first band crosses the wing near the base; the second, third and fourth are confluent anteriorly about the middle of the wing margin, and diverge posteriorly; the second band joins the first at the posterior margin of the wing. Fine pubescence covers the wing, white in hyaline parts and black over bands.

Abdomen—Black, crossed with four white bands which border the posterior margins of the second, third, fourth and fifth tergites. Abdomen with seven segments, widening from the first to the third, which is broadest, then rapidly narrowing to the seventh, which has the shape of a truncate cone and forms a firm protection for the ovipositor.

Ovipositor—When not in use, entirely retracted within seventh segment of abdomen. Extended, broadest at base, tapering to a sharp point at tip; horn-like, brownish; a groove in under surface, covered by two flaps extending half-way from base to tip. Sheath of ovipositor thin, with many chitinous projections, the sheath disappearing withing the last abdominal segment when ovipositor is retracted.

Adult Male. General appearance similar to that of female, but smaller. Length 4.5 mm.

The markings of head, thorax and wings are identical with those of the female.

Abdomen—With seven segments, but apparently with only five because the sixth and seventh are retracted beneath the fifth. White bands border the posterior margins of the second, third and fourth tergites. The sixth segment is unsymmetrical, reduced on the right side. The seventh bears a pair of chitinous appendages. There is a very long, slender, chitinous penis, which is retracted into a pocket beneath the fifth tergite.

The Egg. Length 1 mm., width .25 mm. Shining white. Obtusely rounded at one end, somewhat tapering at the other. The blunt end provided with a short pedicel. This end covered with a network of ridges forming irregular hexagons, smaller at the end of the egg, larger and more regular toward the middle, becoming faint and gradually disappearing one third to one half away from pedicellate end to pointed end of egg. Pedicellate end of egg slightly darkened.

The Larva. Length, full-grown, 7 to 8 mm. Color white, or sometimes slightly yellowish or greenish. Anterior end pointed; posterior end somewhat blunt. Fourteen segments. The body thickest at the ninth to the eleventh; narrowing gradually and then rapidly to the first; narrowing slowly from the eleventh to the fourteenth. The fourteenth segment has the dorsal surface cut off diagonally downward. On this surface are two caudal spiracles. Within the second, third and fourth segments is a chitinous framework, visible by transmitted light, which anchors a pair of black, chitinized, rasping hooks, projecting from the basal surface of the first segment. The first three segments are retracted into the fourth when the larva is disturbed. At the union of the third and fourth segments, on each side of the dorsal surface, is a yellowish, funnel-shaped, cephalic spiracle, connected

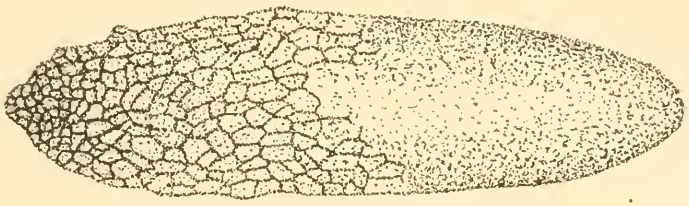


Fig. 2. Egg of the Apple Maggot—Enlarged.

by a tracheal tube with the corresponding caudal spiracle. Transverse tracheal tubes connect the lateral tubes immediately anterior to the fifth and fourteenth segments.

The Pupa. The pupa is enclosed within the shortened and hardened larval integument, forming the puparium. The latter is brownish, oval, the two ends somewhat evenly rounded. Length 4.5 mm.; width 2.25 mm. The first three segments of the larval integument are contracted, so that the cephalic spiracles project anteriorly. The last segment contracted slightly but the caudal spiracles remain visible. The pupa within is white, the head tipped ventrally, the legs and wing buds closely folded.

CONTROL MEASURES DIRECTED AGAINST THE ADULT.

From the beginning of this investigation hope was entertained that some measure of control might be devised directed

toward the adult stage, to supplement or replace the method of keeping drops picked up.

As study of the insect proceeded it was found that there are facts in its life history and habits that have a vital bearing in judging the apparent benefit of any such proposed measures. These facts are as follows:

The adults of this species are not ordinarily characterized by general and free flight throughout a section, as with many other pests. If fruit of attractive qualities is at hand the flies are localized in their habits. This means that measures directed against the adult stage in a given case can be interpreted only on the basis of definite knowledge that there was an ample supply of adults in and about the trees, capable of egg laying.

To be certain that such supply exists one must ordinarily know:

That there was an abundance of infested fruit on the trees the previous season;

That this fruit was allowed to decay on the ground beneath the trees;

That it was of such variety that decay would take place in time to permit the maggots to mature and leave it before cold weather;

That circumstances did not exist unfavorable or fatal to the pupa in the soil.

Further facts to be recognized are the following:

If the trees under experiment are not of variety especially attractive to the adults, and are adjacent to others that are attractive and that are in fruit, there may be a movement toward the latter.

A count of egg punctures can alone determine the actual infestation following treatment. Trees may bear a small amount of fruit one season, and this fruit be so badly punctured as obviously to be worthless. If such conditions prevail the year preceding treatment, and if there is a large amount of fruit the year when treatment is given, not only may there be less adults because of unfavorable concentration the previous season, but the egg punctures will be so distributed that the fruit may appear fairly free, although the total number of egg punctures may be the same.

Occasionally fruit of a hard or late variety is badly attacked in

a season of abundance of the adults when adjacent early or attractive trees have failed to fruit. Yet such fruit, except for the early drops, may mature few larvæ. Thus in spite of heavy infestation the previous season there may be very few adults about in the year of treatment.

There are years of comparative scarcity of adults, due to a combination of circumstances. Apparent results in such years are apt to be untrustworthy.

It will be noted that these factors apply particularly to the judgment of results of treatment that appear *favorable*. If the treatment for the adults gives *unfavorable* results it is of little moment whether the flies came from the trees under treatment or elsewhere; the treatment was in any event unsuccessful in its net results.

POISON BAIT SPRAYING.

In South Africa and elsewhere, in the case of the Mediterranean Fruit Fly and some other species, apparently favorable results have been recorded from spraying with a combination of sweets and an arsenical applied as a poison bait for the adult females. The feeding habits and other characteristics of the Mediterranean Fruit Fly are, however, known to be different from those of the Apple Maggot. For example, the former seems noticeably attracted to various substances available for baits, including even kerosene; again the adults frequent fallen fruit.

In the discussion of the response of the adults of the Apple Maggot to baits, and their feeding habits, as detailed earlier in this bulletin, it was stated that there was no noticeable attraction to sweets. Nevertheless it was hoped that the adults might respond to a more wholesale distribution of the bait, such as would be afforded by suitable spraying.

With this in view, experiments in poison bait spraying were begun in 1910. These first experiments were for the most part without sufficient check as to the actual abundance of flies in the trees treated. The importance of this factor was not then understood.

In 1911 experiments were continued. Spraying operations were conducted at various points. Account was taken of attendant conditions. Results were based on actual counts of egg punctures.

No spraying was done in 1912 because of comparative scarcity of adults.

In 1913 poison bait sprays were again tried on a still larger scale. Precautions were taken as before to safeguard against unwarranted deductions from apparently favorable results.

The bait used each year contained some form of sweets as the element of attraction. This consisted of sugar, or molasses, or sometimes glucose. The poison employed was arsenate of lead. The amount of sweets and the proportion of poison varied. In no case was a soluble arsenical used. It was believed then and is considered now that the employment of such a material, resulting invariably in the destruction of all foliage that receives it, must be a drastic remedy of last resort.

The net results of all these experiments were in essential agreement, and may be summarized as follows: Poison bait sprays, as so far devised, have entirely failed to insure protection of the fruit of the sprayed trees from attack by the maggot. In part of the experiments there was apparently some improvement of the fruit, especially in isolated trees. This may have resulted from the death of flies because of the sprays; or it may have been due to various other factors. The important point is that no such protection was forthcoming as would be essential if the treatment were to be ranked as an effective means of control.

Even with 6 to 10 applications in a season, keeping fruit and foliage thoroughly and constantly coated throughout the activity of the flies, the apples often showed abundant egg punctures. One of the worst lots of apples examined in all of the investigation, from the standpoint of the number of egg punctures, was the fruit from a Porter tree that had received seven applications of a poison bait spray. The maximum number of egg punctures ever recorded in a single apple—46—was found on this tree. There were many apples on it with 20 or more punctures. The fruit was so thoroughly coated with the spray material that it was necessary to wipe it before counting the punctures.

The above conclusions should not be taken as asserting that no flies are poisoned by such sprays. Some flies may be. Indeed it may be, as will be noted later, that with ordinary spraying of apple trees with a simple solution of arsenate of lead and water for some other insects, such adults of the Apple Maggot as chance

to feed or drink at spots where poison has persisted may be killed. The conclusion offered is that the adults are not materially attracted to the bait, and that such sprays, or any others so far devised, are without any adequate avail as definite and sufficient protection of the fruit, in the absence of other treatment.

For the purpose of setting forth data on which the above conclusions are based, records will be quoted below of various lots of sprayed trees, choosing for the most part only typical lots in which surrounding conditions were accurately known. It is deemed unnecessary to quote all of the many lots sprayed in the course of the three years' work. The detailed records of egg punctures will be found in Table 26.

RECORDS OF EXPERIMENTS WITH POISON BAIT SPRAYS.

Season of 1910. 1. Variety, Winter Sweet. Tree located in pasture eighteen yards from Tree 5, below. Fruit infested for a number of years. Bore the previous year, and drops lay in grass. Formula, arsenate of lead $1\frac{1}{2}$ pounds, molasses 3 gallons, water 15 gallons. Three applications: July 13, 28, August 6. Applied with bucket pump, $2\frac{1}{2}$ gallons to each application. Results: total apples examined, 2,499; total punctures, 7,205. Proportion free from punctures, 14 per cent.

2. Check tree of same variety as the above, and located at another part of pasture. No spray applied. Total apples examined, 1,538; total punctures, 10,523; proportion free from punctures, .5 per cent.

3. Variety, President. Tree located in corner of very wide stone wall and adjacent to other trees, principally Gravenstein, Baldwin and Spy. Fruit badly infested in 1909, and many drops always lodged in stones of wall. Formula, arsenate of lead 1 pound, molasses 2 gallons, water 15 gallons. Four applications, made by owner of premises, July 8, 21, 27, August 13. In the words of the owner, the tree was kept well coated with the material. Results: drops examined, 429; total punctures, 1,525, proportion free from punctures, 0 per cent; picked examined, 488; total punctures, 1,520; proportion free from punctures 8.1 per cent.

TABLE 26.

Counts of Egg Punctures in Some Fruit Recorded in Experiments with Poison Bait Sprays.

For account of conditions applying to each lot, applications of spray, etc., see details under Records of Experiments.

Lot No.	Variety apples.	Number of apples recorded with egg punctures indicated at top of columns.																																													
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
1	Winter Sweet	340	469	431	404	358	182	126	84	34	30	29	5	4	1	2																																
2	Winter Sweet	7	42	76	130	153	195	178	170	103	123	99	59	55	42	20	19	7	11	5	7	0	0	0	0	1	0	0	1																			
3	President	40	148	168	166	149	117	74	25	18	3	7	2																																			
4	Granite Beauty	671	349	119	39	18	4	2																																								
5	Granite Beauty	545	242	126	54	29	19	10	4	1	0	2	0	0	0	0	0	1																														
6	Sops-of-Wine ..	566	297	133	47	29	14	12	1	1	0	1																																				
7	Porter........	293	152	59	19	7	4	0	1																																							
8	Porter........	1003	348	170	97	53	12	11	4	4																																						
9	Porter........	250	274	164	116	67	40	20	7	8	2	1	1																																			
10	Porter........	0	0	0	3	1	2	2	0	5	4	14	10	19	22	5	13	22	12	18	12	20	16	21	13	16	5	18	19	14	3	3	4	4	1	3	4	0	1	1	2	2	0	0	0	0	0	1
11	Sweet.........	20	32	31	46	48	53	48	37	31	49	22	26	26	20	17	11	9	10	4	8	2	5	3	1	2	3								1				1									
12	Williams......	6	17	20	21	11	11	10	15	15	10	12	5	1	2	0	2	1	0	0	1																											
13	August Sweet..	39	55	42	37	31	30	25	26	18	12	6	7	1	1	0	0	0	2																													
14	August Sweet..	6	5	5	2	4	2	6	13	11	12	16	31	20	9	3	2	4	5	1	2	3	0	4	2	1																						
15	Snow.........	44	79	65	65	52	20	25	27	17	19	19	11	10	10	7	3	2	1	0	0	2	1																									
16	Porter........	27	38	39	38	31	19	15	11	4	1	2	1																																			
17	Porter........	23	18	58	62	51	55	61	59	42	50	30	27	21	16	22	16	9	7	6	3	3	3	3	2	3																						
18	Porter........	0	4	5	19	19	24	25	36	32	35	31	29	29	30	30	23	18	14	9	5	9	6	5	4	2	0	0	0	2	0	1																
19	Grimes Golden.	131	72	57	31	23	23	14	11	9	2	1	0	0	0	0	1	0	1																													
20	Grimes Golden.	124	116	88	55	30	17	7	1	6	0	3	0	0	0	0	1																															
21	Grimes Golden.	303	30	12	0	1	0	0	1																																							
22	Grimes Golden.	338	100	41	7	3	0	1																																								

Season of 1911. Variety, Granite Beauty. Tree located in open field, thirty-five yards from check tree of same variety, as recorded below. Fruit somewhat infested in prior years. In bearing the previous season, and drops lay, but amount unknown. Formula, arsenate of lead 1 ounce, molasses 1 quart, water 1 gallon. Ten applications made: June 27, 30, July 8, 18, 22, 25, 31, August 16, 20, 26. The first application made by sprinkling the tree with a broom; all others made with a hand pump. Amounts of material used, 7½ quarts for the first application, 5 for the second, 7½ for the third, 7 for the fourth, 8 for the fifth, and 7 for each of the succeeding. Thirty-three adults released beneath tree July 8, and 17 July 18. Results: total drops examined, 1,202, total punctures, 808; proportion free from punctures 55.8 per cent. Picked fruit apparently the same.

5. Check tree of same variety, and same history; distant thirty-five yards, from sprayed tree and eighteen yards, in opposite direction, from infested and sprayed Winter Sweet. No spray applied. Total drops examined, 1,033; total punctures, 999; proportion free from punctures 52.7 per cent. Picked fruit apparently the same.

6. Variety, Sops-of-Wine. Location, standing somewhat isolated in a hayfield, fifty yards from a small group of trees of winter varieties except for one Williams Favorite, and fifty yards in the opposite direction from an infested Porter and a seedling tree. Three trees of winter varieties twenty yards away, across road. Fruit infested in 1910, and at least part lay on the ground. Formula, arsenate of lead 1 ounce, molasses 1 quart, water 1 gallon. Seven applications made, June 27, 30, July 8, 18, 22, 25, 31. First application, 7½ quarts, made by sprinkling with broom. Subsequent applications, 5 quarts each, made with bucket pump. Thirty flies released beneath tree July 8. Results: drops examined, 619; total punctures, 510; proportion free from punctures, 55.8 per cent; picked examined, 477; total punctures 447; proportion free from punctures 46.1 per cent.

7. Variety, Porter. Location, somewhat isolated, fifty yards to nearest tree of a row of Baldwins, not infested. Fruit infested in 1910, and drops lay, but amount of drops not known. Formula, arsenate of lead 1 ounce, molasses 1 quart, water 1 quart. Nine applications made, July 1, 7, 8, 21, 26, 31, August 16, 19, 26.

Applications made with bucket pump. Four quarts of material used for each. Fifty-five flies released beneath tree July 1. Results: drops examined, 183; total punctures, 169; proportion free from punctures, 46.4 per cent; picked examined, 352; total punctures, 213; proportion free from punctures, 59. per cent.

Season of 1913. 8. Variety, Porter. Location, Chart 3, Tree 5. Fruit somewhat infested in 1912, and apples lay on ground,

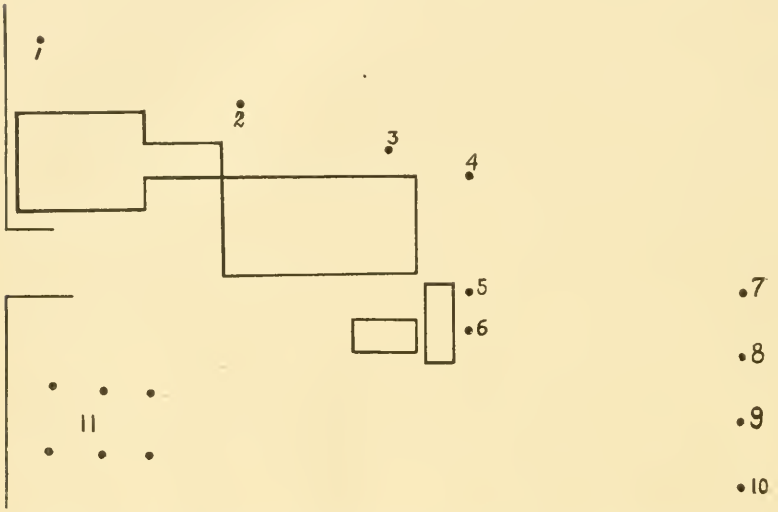


CHART 3. Location of trees in poison bait spraying. Tree 5 sprayed Porter, experiment 8; tree 6, check Porter, experiment 9. Scale, 1 inch = 60 feet.

1. McIntosh.
2. McIntosh.
3. Wealthy.
4. Russet, variety unknown.
5. Porter.
6. Porter.
7. Nonesuch.
8. Gravenstein.
9. Gravenstein.
10. Winter, variety unknown.
11. Orchard, about all Baldwins.

but chickens ran under tree. Formula, arsenate of lead 1 ounce, molasses 1 quart, water 4 quarts. Five applications made, July 9, 12, 25, August 6, 14. Applications were made with a hand pump. The amount of material used was $7\frac{1}{2}$ quarts for each of the first three applications, 5 for the fourth and 4 for the fifth. All drops were recorded and all remaining fruit picked and recorded. Results: total drops, 762; total egg punctures, 1,007; proportion free from punctures, 39.3 per cent; total picked, 940; total punctures, 370; proportion free from punctures, 74.7 per cent.

9. Check to the above. Variety same. Location, Chart 3, Tree 6. History for prior year the same as sprayed tree. No spray applied. All drops recorded and all remaining apples picked and recorded. Results: total drops, 606; total punctures, 1,262; proportion free from punctures, 22.6 per cent; total picked, 344; total punctures, 455; proportion free from punctures, 32.8 per cent.

10. Variety Porter. Location, Chart 4, Tree 5. Fruit in-

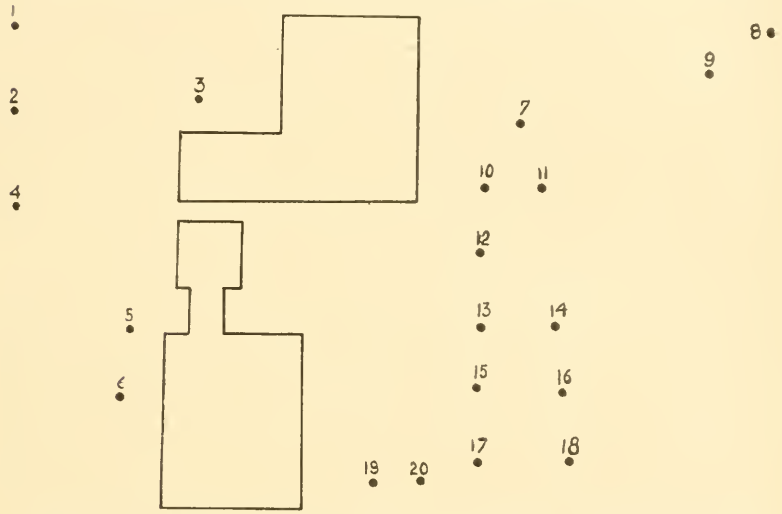


CHART 4. Location of trees in poison bait spraying. Tree 5, sprayed Porter, experiment 10. Tree 12, check sweet, experiment 11. Scale 1 inch = 60 feet.

1. Porter.
2. Russet.
3. Russet.
4. King.
5. Porter.
6. Spy.
7. Stevens.
8. Gravenstein.
9. Mann.
10. Sweet.
11. Russet.
12. Sweet.
13. Astrachan.
14. Greening.
15. Baldwin.
16. Natural fruit.
17. Fall, variety (?).
18. Fall, variety (?).
19. Stevens.
20. Spy.

fested in 1912 and drops not gathered, but some fruit probably eaten by hogs which had access to space beneath this tree as part of large run. Formula, arsenate of lead 1 ounce, molasses 1 quart, water 3 quarts. Seven applications made, July 9, 12, 25, August 6, 14, 23, September 6. Applications were made with a hand pump, 4 quarts of material at each application. All apples picked and recorded. Results: total apples, 349; total punctures, 6, 810; proportion free from punctures, 0 per cent.

11. Check to the above. Variety, unknown sweet. Location, Chart 4, Tree 12. Fruit infested the prior season and most drops allowed to remain, but apples that appeared sound sometimes picked up. Chickens had access to space beneath tree. No spray applied. All drops were recorded. About 1 bushel of fruit was picked from the tree and examined. Results: total drops, 198; total punctures, 1,275; proportion free from

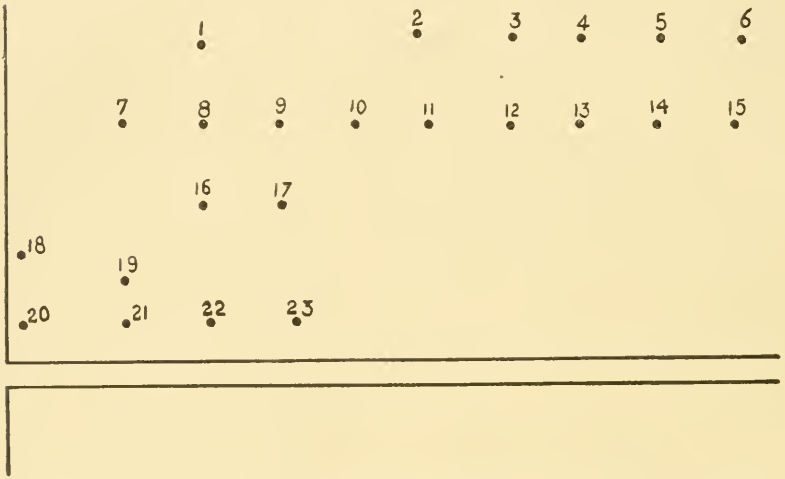


CHART 5. Location of trees in poison bait spraying. Tree 21, sprayed Williams Favorite, experiment 12. Tree 17, sprayed August Sweet, experiment 13, Tree 16, check August Sweet, experiment 14. Scale 1 inch = 60 feet.

1. Gravenstein.
2. Early Winter Sweet.
3. Spy.
4. Spy.
5. Spy.
6. Spy.
7. Winter Sweet.
8. Orange Sweet.
9. Russet.
10. Sweet, variety (?).
11. Plum.
12. Baldwin.
13. Plum.
14. Porter.
15. Baldwin.
16. August Sweet.
17. August Sweet.
18. Baldwin.
19. Hubbardston.
20. Baldwin.
21. Early Williams.
22. Lady Sweet.
23. Hubbardston.

punctures, 8.5 per cent; apples picked, 358; punctures, 3,086; proportion free from punctures, .8 per cent.

12. Variety, Williams Favorite. Location, Chart 5, Tree 21. Fruit considerably infested in 1912, and a large crop borne. Apples that appeared sound were gathered for use, the rest rotting on the ground. Formula, arsenate of lead, 1 ounce, molasses 1 quart, water 3 quarts. Four applications were made, of 4 quarts each, applied with a hand pump. Dates of applications,

July 11, 22, 26, August 5. The fruit was picked August 8, and all apples recorded. Results: total apples, 160; total punctures, 872; proportions free from punctures, 3.7 per cent.

13. Variety, August Sweet. Location, Chart 5, Tree 17. The history of fruiting for 1912 was the same as that of the preceding. Four applications of spray made. Formula used, manner and dates of application, and amount of material employed identical with the preceding. Apples picked August 8. Results: total

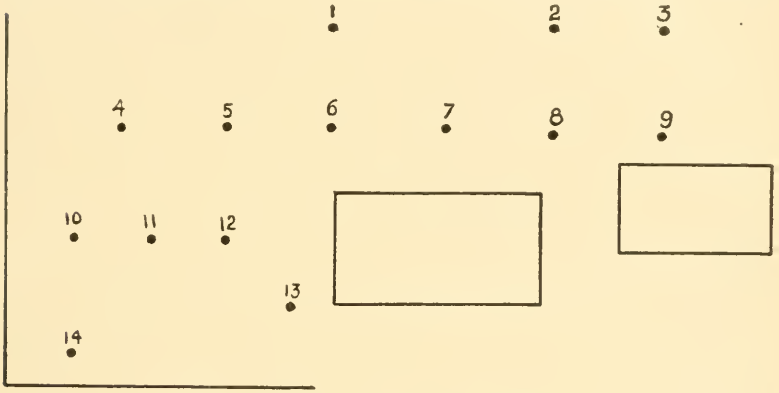


CHART 6. Location of trees in poison bait spraying. Tree 1, sprayed Fameuse, experiment 15. Tree 9, sprayed Porter, experiment 16, Tree 2, sprayed Porter, experiment 17. Tree 8, check Porter, experiment 18. Scale 1 inch = 60 feet.

1. Snow.
2. Porter.
3. Porter.
4. Baldwin.
5. Baldwin.
6. Baldwin.
7. Spy.
8. Porter.
9. Porter.
10. Baldwin.
11. Baldwin.
12. Baldwin.
13. Baldwin.
14. Baldwin.

apples, 332; total punctures, 1,304; proportion free from punctures, 11.7 per cent.

14. Check to the above. Variety, August Sweet. Location, Chart 5, Tree 16. History for 1912 same as the preceding two. No spray applied. Apples picked and recorded August 8. Total apples, 169; total punctures, 1,732; proportion free from punctures, 3.5 per cent.

15. Variety, Fameuse. Location, Chart 6, Tree 1. In 1912 tree bore well, apples badly infested. Drops rotted on the ground. Formula used, arsenate of lead 1 ounce, molasses 1 quart, water 3 quarts. Seven applications made, July 11, 22, 26, August 5, 23,

27, September 5. Four quarts of material used for each application, and all material applied with a hand pump. All drops were gathered and recorded. About 1 bushel of fruit remaining on the tree was removed and recorded. Results: total drops, 198; total punctures, 1,575; proportion free from punctures, 0 per cent; apples picked, 281; total punctures, 579; proportion free from punctures, 15.6 per cent.

16. Variety, Porter. Location, Chart 6, Tree 9. History for 1912 same as the preceding. Seven applications made. Formula used, dates of applications and manner and amounts same as the preceding. About 1 bushel of fruit picked from the tree and recorded. Results: apples examined, 226; total punctures, 688; proportion free from punctures, 11.9 per cent.

17. Variety, Porter. Location, Chart 6, Tree 2. History for 1912 same as the preceding. Seven applications made. Formula used, dates of applications and manner and amounts same as the preceding. All drops recorded. All remaining apples on the tree picked and counted. Results: total drops, 417; total punctures, 3,548; proportion free from punctures, .4 per cent; total picked, 234; total punctures, 1,167; proportion free from punctures, 9 per cent.

18. Check to the preceding. Variety, Porter. Location, Chart 6, Tree 8. History for 1912 same as the preceding. No sprays applied. All drops gathered and recorded. Total drops, 446; total punctures, 4,785; proportion free from punctures, 0 per cent.

19–21. Three trees of Grimes Golden. Location, Chart 7, Trees 23, 24, 25. In 1912 each tree bore well, the fruit infested, some drops picked up occasionally, the remainder allowed to lie. Formula used on each tree, arsenate of lead 1 ounce, molasses 1 quart, water 3 quarts. Ten applications given to each tree, July 11, 19, 22, 26, 30, August 5, 11, 23, 27, September 5. Four quarts of material applied to each tree at each application. A hand pump used. Each tree bore a large crop. From each about 1½ bushels of apples were removed and recorded. Results of each: Tree No. 1, apples counted, 376; total punctures, 779; proportion of apples free from punctures, 34.8 per cent. Tree No. 2, apples counted, 448; total punctures, 808; proportion free from punctures, 27.9 per cent. Tree No. 3, apples counted, 347; total punctures, 65; proportion free from punctures, 87.3 per cent.

22. Check to the above. Variety, Grimes Golden. Location, Chart 7, Tree 22. Prior history and present fruiting the same as the preceding. No sprays applied. About 1½ bushels of apples were removed and recorded. Total apples examined, 490; total punctures, 221; proportion free from punctures, 68.9 per cent.

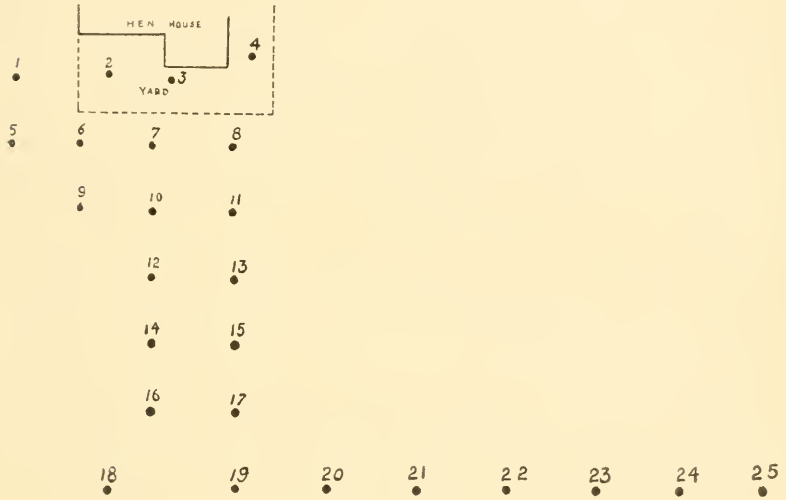


CHART 7. Location of trees in poison bait spraying. Trees 23, 24, 25, sprayed Grimes Golden, experiments 19, 20, 21. Tree 22, check Grimes Golden, experiment 22. Scale 1 inch = 60 feet.

1. Baldwin.
2. Gilliflower.
3. Baldwin.
4. August Sweet.
5. Gilliflower.
6. Greening.
7. Baldwin.
8. Baldwin.
9. Pippin.
10. Greening.
11. Porter.
12. Baldwin.
13. Tolman Sweet.
14. Baldwin.
15. Baldwin.
16. Baldwin.
17. Baldwin.
18. Gravenstein.
19. Snow.
20. Snow.
21. Snow.
22. Grimes Golden.
23. Grimes Golden.
24. Grimes Golden.
25. Grimes Golden.

Discussion. In experiments by Illingworth (34, p. 167) favorable results were considered to follow certain trials of poison sprays. The writer must admit to a belief that the tests described may not have been extensive enough or sufficiently safeguarded in the matter of attendant circumstances, as suggested earlier in this bulletin.

RELATION OF CODLING MOTH SPRAYS.

In the experiments described above, it has been proved that even ten applications of a poison bait spray, keeping the material thoroughly in evidence throughout the season of the adult flies, failed to give protection from attack by the maggot. This being true, it appears to the writer self-evident that the ordinary spraying for codling moth will not in itself afford protection.

The material used in codling moth spraying contains no greater quantity of poison than was employed in the above experiments, and frequently less. Furthermore, the first application for codling moth is made from three to four weeks before the earliest adults of the maggot make their appearance, and the second application, if one is given, is made from two to four weeks before the maximum emergence of the adults.

In studies of New Hampshire orchards many were found in which thorough spraying for codling moth was done, yet attack by the maggot on certain trees persisted undiminished, if conditions in the matter of susceptible variety and neglect of the drops were favorable to the maggot.

However, that there is an indirect benefit from ordinary codling moth spraying the writer believes certain; and this effect may be of material help. These results appear to be as follows:

Apple trees well sprayed for codling moth are presumed to drop their fruit less early, less continuously, and in less quantity than unsprayed trees. Such lessening of dropping reduces the opportunity for the maggot to mature and leave the fruit, and thus results in an increased percentage of mortality of the egg and larval stages. The effect of this, after two or three seasons, would be a diminishing amount of infestation.

Combined with this there may be some killing of adults from chance feeding or drinking at spots where drops of poison persist.

The part these benefits may play in comparative infestation in various types of orchards will be noted below in a discussion of the effects of general orchard practice.

POISON TRAP PANS.

The action of adults in the presence of various substances offered them in confinement has been noted earlier in this bulletin, in the discussion of feeding habits. Reference will be

found there also to experiments by Ross (55, p. 68) with pans containing baits and hung in trees.

In 1912 16 pans were prepared. Fifteen of these contained a solution made up at the rate of arsenate of lead 1½ ounces, molasses 2 quarts, water 2 quarts. One pan contained a solution made up in a similar manner, but substituting 4 pounds of brown sugar for the 2 quarts of molasses. To each pan was added 5 drops of oil of rhodium. These pans were hung in various trees that had been badly infested with the maggot, the trees located in orchards some miles distant from Durham.

Other matters interfered with observation of the pans. At the close of the season their contents were brought to Durham. They had caught a large and heterogeneous mass of insect life. A part of this material was gone over, but no traces of adults of the maggot were discovered. It should be noted, however, that the season was one of comparatively light infestation, and adults may not have been abundant in the localities in question.

CONTROL MEASURES DIRECTED AGAINST THE LARVA.

The only vulnerable point in the larval stage made clear in this investigation is the fact that fruit must drop from the tree and reach a favorable degree of mellowness before the larva can mature and leave it.

CONTROL BY PICKING UP DROPS.

The experiments already described determining the length of time after the fruit falls before the larvæ issue from it are believed to supply the most trustworthy data obtainable on control by picking up drops. The bearing of these data on a plan of control, taking into account the behavior of different varieties of apples, the influence of the time when dropping takes place, and the dispersion habits of the adults, will be given later in recommendations for control.

In a study of conditions prevailing in many orchards in New Hampshire it was found that most growers, in ordinary farm orchards, take little heed of the drops, often confining their efforts to a single cleaning up in October or failing to take into account the worthless, infested early fruit. Others following right

methods and taking pains to secure all drops at reasonable intervals, have practically eliminated the pest as a factor of consequence in their orchards. In these places apples of susceptible varieties, such as the Porter, are being grown free of the maggot, provided uncared-for trees are not closely adjacent.

THE USE OF LIVE STOCK TO KEEP DROPS CLEANED UP.

The effectiveness of the larger farm animals, pigs, sheep or cattle, as a means of keeping fallen infested fruit cleaned up, depends solely on the ability and willingness of the animals to dispose of the drops as they fall. If the drops fall in too great quantity for the live stock at hand to dispose of reasonably soon, more or less larvæ will mature and enter the ground, to cause reinfestation the following season. If some of the drops fall outside the enclosure in which the stock range, or if drops lodge in stone walls, reinfestation will certainly occur. The above facts are self-evident on second thought, but sometimes are lost sight of in estimating the benefits that have been or may be derived from the use of live stock. It must be remembered also that some pupæ already in the soils may not emerge until the second season.

Hogs. That hogs are fond of apples is well known to any farmer. Sweet fruit, which chances to be the kind often badly infested by the maggot, is especially relished.

In the course of these investigations many instances were observed where marked benefit followed after hogs had been allowed access to the ground beneath trees infested by the maggot. Invariably such benefit is substantial only when the animals are sufficiently limited in their range to make certain that they will dispose of all drops, and when their enclosure is so planned that they can secure all infested fallen fruit. When this is done hogs may be the means of eliminating the maggot from badly attacked trees of susceptible varieties.

Unfortunately there are numerous and unquestionable records of damage to apple trees by hogs. This damage may reach the point of killing the trees, or at any rate badly injuring them. On the other hand, there are equally authentic instances where no apparent injury whatever has been done the trees.

An attempt was made to find out how hogs might be used

safely, by appealing to the experience and observation of horticulturists and of many growers. The attempt failed to materialize foundation for specific conclusions, but did bring out many interesting experiences.

Of the horticulturists, three believed the practice of permitting hogs in orchards a dangerous one; four considered that with reasonable precautions the plan may be followed with safety.

From their letters the following observations are quoted:

"Hogs are often kept in orchards for years without damage to the trees. Then . . . a few or all of a herd will begin destroying the roots of apple trees or even strip the barks from trunks. Ringing their noses will help keep them out of mischief, but even with rings in their noses I have known hogs to do a good deal of damage in an orchard"; " . . . if the hogs are well fed and watered I do not believe they will damage the trees in the least. I have known of several cases where they have been used in this way without any damage whatever"; " . . . in my experience the injury by hogs has taken place in those orchards where the hogs were not provided with charcoal and mineral matter in abundance. Where charcoal has been given I know of no serious injury whatever"; "I have never known of any marked injury from the pasturing of hogs in an apple orchard where the hogs were given plenty of room and fed outside the orchard."

In the course of a questionnaire submitted to New Hampshire growers two questions were asked concerning hogs, as follows:

1. Have you known of hogs injuring apple trees, by stripping the bark from the trunks, etc., when kept in an orchard through summer?

Fifty-two growers replied "Yes" to this question. Sixty-three growers answered it with "No."

2. Have you known of hogs being kept in an orchard for one or more seasons without injury to the trees?

Sixty-nine growers answered this question with "Yes." Thirty-five answered it with "No."

Many growers supported their replies with comments and experiences of great interest. Space will permit quoting only a few of these, as follows:

"I had one sow and ten pigs in an enclosure (one fourth acre).

They were in this enclosure three years in succession. The first year they plowed the ground. The second year they uncovered the roots of some of the trees. The third year they stripped the bark from two of the trees, which caused them to die. I gave them plenty of skim milk with shorts while there."

"To my knowledge hogs in large enclosures, with plenty of grass and weeds, do not strip the bark from trees."

"I have a pasture of about four acres containing about 200 apple trees. Hogs have pastured there for twenty years, varying in number from 5 to 30. The trees stand there to-day, thrifty and vigorous, and not one that the hogs injured by stripping the bark from the trees. On the other hand they have helped the trees very materially by rooting the sod, by fertilizing the land, and by picking up the windfall apples. My opinion is that . . . hogs will bark apple trees when they are confined in a small enclosure . . . but not when they have a good range."

"We have an orchard that hogs have been kept in for the last forty years, year after year. They never hurt the trees. But there was plenty of grass for them, and the trees were old ones and quite large. I have an idea that they would hurt young trees."

"Have had hogs injure trees when too closely confined, and grass became short. Give them plenty of run, and enough to eat and drink, and they will not bark trees."

Cows—Sheep—Poultry. Frequently, on New Hampshire farms, some apple trees stand in pastures where cattle or sheep range. If such trees are so located that the livestock can get at all drops, and if they are in a part of the pasture frequented by the stock, they may remain free of the maggot. Occasionally growers permit cattle or sheep to range through planted orchards, where the trees are old and large, with branches high from the ground.

Poultry are not able to dispose of infestation by the maggot unless large numbers are confined to a limited area. Apparently about 500 hens to an acre are required, depending on the size of the trees and the relative amount of early and susceptible fruit. If the trees are small the number may be less.

It is believed, in the light of some experiments described below, that a considerable part of the value of poultry may lie in their ability to find and destroy pupæ in the soil, and to a less extent, probably, their ability to catch and eat newly emerging flies.

CONTROL MEASURES DIRECTED AGAINST THE PUPA.

USE OF POULTRY.

In a number of places noted in observational records poultry have been found to serve as efficient checks of the maggot in trees located within the runs. If the ground is well worked over by the poultry it may be inferred that pupæ are found and destroyed by them.

In June, 1911, four cages were arranged near the insectary at Durham. Each cage was 4 by 4 feet square, and was covered with screen wire of the mesh used for fly screens.

Cage 1 was on sod, over a space where 1 bushel of infested Red Astrachan apples had been allowed to rot the previous August.

Cage 2 was on sod. Three quarters of a bushel of infested Sops-of-Wine had been placed here the previous summer.

Cage 3 was located over a space where seven eighths bushel of infested Gravensteins had rotted the previous August. This ground was spaded when the cage was placed in position.

Cage 4 covered a space where miscellaneous infested apples had decayed the previous year. This ground was spaded before placing the cage in position.

Before setting up the cages 100 pupæ were buried at a depth of an inch or two in the ground covered by each cage. These were in addition to the pupæ that might be in the soil from the decaying apples of the prior year.

One hen was introduced into each cage June 16, and thereafter each cage was watched for adults of the maggot. The hens used were as follows: No. 1, Buff Leghorn; No. 2, White Leghorn; No. 3, Plymouth Rock; No. 4, White Leghorn. In Cage 2 the hen died June 28. Her place was taken by another of the same breed. In Cage 4 the hen died July 3, her place being taken by a black hen of unknown breed.

The record of flies observed in each cage was as follows:

In Cage No. 1, 1 fly, found June 29.

In Cage No. 2, 13 flies, found June 28 to July 8. This is the cage in which the hen was sick and inactive.

In Cage No. 3, 6 flies, found June 26.

In Cage No. 4, no flies.

It is not known, of course, how many flies that otherwise might

have escaped capture were caught by the hens because confined by the screens. Apparently the hens were not disposed to or able to catch flies resting on the inside of the upper part of the screen.

Later in the summer an additional experiment was carried out with Cages 1, 3 and 4, as follows:

The same hens remained in each cage. September 12, 100 pupæ were buried two inches deep in the center of each cage.

September 15 the surface soil beneath Cage 1 was removed and examined. No pupæ were found.

September 19 the surface soil beneath Cage 3 was removed and examined. Two pupæ were found.

September 22 the soil beneath Cage 4 was similarly examined. Seven pupæ were found.

USE OF CHEMICALS IN THE SOIL.

Experiments were carried out in 1911 looking toward the possible use of some insecticide in or on the soil beneath infested trees to destroy the vitality of the pupæ in the soil or to prevent emergence of the adults.

In preparation for these experiments various lots of infested apples were placed the prior year both on sod ground and on ground free of sod, and were allowed to decay there. As noted in the table giving results of the experiments, in several cases pupæ were buried in the soil before applying the material.

The area treated in each case was one square yard.

Immediately after making the applications, screen-wire cages were placed over the ground treated, and these were watched daily throughout the rest of the season for adults emerging.

In estimating results it should be remembered that other experiments have since determined that some individuals remain two years in the pupal stage. This does not materially affect matters where ample emergence occurred in spite of the treatment given; but in the few cases where emergence was light the cause may have been partly due to this two-year phase.

As the tabulations indicate, not much of promise was disclosed by the experiments. In two treatments using kerosene emulsion, and in one of two using Phinotas oil, comparatively few adults emerged. Yet with the emulsion used at the rate of one-

half gallon of the stock solution to a square yard, as indicated in the table, a heavy dose of oil and a large quantity of water would be necessary to secure equivalent treatment for all the ground beneath a single tree. An English material, known as Clift's Insecticide, was used in one case, mixed with the surface layer of soil to a depth of two and one-half inches. In this case no adults emerged. In another case where this same material was spread over the surface of sod ground there was a heavy emergence of adults.

TABLE 27.

Results of Applying Insecticides to Soil, June 17–19, 1911.

Surface of ground.	Infested apples placed in prior year.	Additional pupæ buried.	Treatment.	Number adults emerged.
Sod.....	1 bu. Aug. 16 Red Astrachan	200	½ gal. stock solution Kerosene Emulsion + 6 gals. water	2
Sod.....	1 bu. Aug. 17 Fall Jennetting	200	None	140
Sod.....	None	200	4 oz. Black Leaf 40 + 6 gals. water	203
Sod.....	1 bu. Aug. 17 Fall Jennetting	200	1 lb. Clift's Insecticide spread on surface of sod	144
Bare....	None	200	1 lb. Clift's Insecticide mixed with surface layer of soil	0
Bare....	None	200	None	64
Sod.....	Aug. 15–20 Gravenstein	...	None	260
Sod.....	Aug. 15–20 Gravenstein	200	1 qt. commercial lime-sulfur + 2½ gals. water	252
Bare....	Miscellaneous	...	½ gal. stock solution Kerosene Emulsion + 6 gals. water	5
Sod.....	Miscellaneous	200	1 qt. Phinotas oil + 2½ gals. water	75
Weeds ..	Miscellaneous	...	2 oz. Black Leaf 40 + 6 gals. water	284
Sod.....	Aug. 15–20 Gravenstein	200	1 qt. Phinotas oil + 2½ gals. water	8

BURYING PUPÆ BY PLOWING.

Experiments here and elsewhere have proved that in ordinary soil plowing cannot be expected to bury pupæ deep enough to prevent emergence of the adults.

In experiments in 1910 at Durham 5 lots of 20 pupæ each were buried in sandy soil at depths of 10, 8, 6, 4 and 2 inches. The number of adults emerging from these respective lots was 19, 14, 10, 15 and 16. Similar results were secured from another experiment.

In 1911 five lots of pupæ of 150 each were buried in moist loam at depths of 15, 12, 9, 6 and 3 inches. The emergence of adults from these lots was, respectively, 29, 57, 36, 42 and 69. In other words there was an emergence of over 19 per cent from a depth of 15 inches.

Ross (55, p. 68) buried 100 pupæ at a depth of 6 to 7 inches, and 100 more at a depth of 12 inches. Of the former 41 adults emerged, and of the latter 19.

COMPACTING THE SURFACE SOIL.

In 1911 three lots of 200 pupæ each were buried three or four inches below the surface in a loam soil. In two of these lots the soil was then watered and pounded so as to compact the surface. The remaining lot was left as check.

Screen wire cages were placed over each area, and the emergence of adults recorded.

In one of the lots of compacted soil 1 adult emerged; in the other, none. In the check cage 64 adults emerged.

At another point three similar lots of pupæ were buried in a soil of exceedingly stiff clay. The ground was so hard that a pick was used to loosen it, in order to bury the pupæ. This ground was treated in similar fashion to that described above. In the two treated areas no adults emerged. In the area not treated 3 adults appeared.

The first experiments seemed to indicate that wetting and pounding the surface may have some effect on successful emergence of the adults. As a practical measure, however, in the opinion of the writer it would seldom prove feasible. In addition, the results given are complicated by the possibility that part of the pupæ used may have represented the two-year life cycle, and by the additional fact that predaceous beetles were at work in the soil in this particular experiment.

CULTIVATING THE SOIL.

Ordinary orchard cultivation does not appear to have noteworthy effect on emergence of adults. Trees of susceptible varieties maintained under cultivation, without other practices that would hold the maggot in check, may remain badly infested. Ross (55, p. 69) tried the experiment of giving frequent shallow cultivation to two plots known to contain pupæ; but many adults emerged.

RELATION OF GENERAL ORCHARD PRACTICE TO INFESTATION BY THE APPLE MAGGOT.

Observers frequently have noted that attack by the Apple Maggot often is more severe in small, unsprayed orchards, especially such as are sometimes found adjacent to farm buildings or in connection with village homes. On the other hand, in large commercial orchards the pest may be comparatively rare.

The reasons for this are usually complex. An assumption that any one item, such for example as spraying, is wholly responsible for a lack of infestation may lead to error.

The small orchard is apt to be made up of varieties intended for table use or for home consumption, and in New Hampshire, at least, frequently includes early or sweet fruit. Such fruit is not only especially liable to infestation by the maggot, but affords the condition of early ripening most favorable to continuance of the pest. Extensive commercial orchards in New England usually consist largely of winter fruit. This fruit, as proved in the records set forth earlier in this bulletin, is not of the type well adapted to the life economy of the maggot, which usually meets with heavy mortality in hard, winter varieties. If a commercial orchard does contain blocks of earlier varieties, the fruit is presumably marketed promptly, provided the orchard is treated as a business enterprise. Such practice in itself tends to defeat increase of the maggot.

The small, home orchard is typically more or less neglected. Frequently it is not sprayed; and ordinary spraying, as already noted, may have some indirect effect on infestation by the maggot. Since the fruit is not regularly marketed, or not sent to market at all, only such apples are consumed as the

owner has use for, and then only such as appear sound on the regular occasions when fruit is desired. Fruit that is bruised by falling, is beginning to decay, or is infested, is left to rot beneath the trees—conditions inevitably tending toward persistent infestation. The commercial orchard not only receives regular and thorough spraying for codling moth and apple diseases, with the indirect effect on the maggot that follows such spraying, but the care naturally extends to the product of the orchard and its prompt disposal by sale.

Trees in the home orchard are apt to be located in such places that consistent care of the fruit is difficult. Often, in New Hampshire, such trees are situated in odd corners about the buildings, along a stone wall, or in other similar location. In a commercial orchard conditions are usually the reverse. Facility for proper care of the trees is a leading consideration in their location.

In New Hampshire, small farm orchards are often closely adjacent to neglected, infested wild apples. The prevalence of so-called natural fruit throughout much of the state has already been noted. Its frequent proximity to the home orchard does not tend to reduce infestation of the latter. Trees in a large commercial orchard are apt to be free from this source of trouble.

STORAGE OF APPLES ATTACKED BY THE MAGGOT.

It happens occasionally, in a season of abundance of the maggot, that the commercial grower finds certain winter fruit exhibiting egg punctures, due to flies that have come in from non-fruiting early trees. Such fruit may be but slightly attacked, and if the varieties are of hard, winter sorts, little besides some inconspicuous egg punctures may be in evidence. In other words the fruit may be commercially marketable at picking time.

It is still the practice of some growers to retain the fruit in piles, in the orchard or on the barn floor, for a considerable period after picking. Eventually the apples are barreled, and may pass into the hands of the fruit buyer or may be stored in a farm fruit cellar. Storage in bins in a fruit cellar is practised on occasion.

Observations have shown that when the weather is warm following the picking season, fruit that happens to be attacked by the maggot and is kept for a time in comparative warmth, is

likely to deteriorate rapidly. Development of the larvæ proceeds, and in two or three weeks the apples may be practically worthless.

In 1909–1910 experiments were carried out to observe the action of such fruit in cool and cold storage.

Lot 1 consisted of a box of Baldwins, and was received at Durham October 29. The fruit was examined and repacked, infested fruit in one side of the box and fruit approximately free from punctures in the other side. The infested fruit seemed a little less sound and hard than the other, although development of the larvæ had not proceeded far. The repacked box was placed in cold storage at 32 degrees November 2. It was removed from storage February 10, and was placed in a basement room where the temperature averaged 65 degrees. February 14 the fruit was carefully examined. The condition of the apples had remained essentially unchanged. There was no excessive deterioration of the infested fruit.

Lot 2 was a box of Baldwins, and was examined and repacked in the same manner as Lot 1. Some infestation existed in the half supposed to contain apples free of the maggot. The apples entered cold storage at 32 degrees November 17, and remained until March 10. From March 11 to March 24 they were in the basement room at a temperature averaging 65 degrees. In other words they were given moderate warmth for two weeks following storage. Examination at the end of this period showed for the non-infested section 9 apples rotten and 58 fair; for the infested section 44 apples rotten and 22 fair.

Lot 3 consisted of Baldwins. The non-infested fruit was taken November 16 from a barrel of apples in cellar storage. The apples were sound but not very hard. The infested fruit came from an orchard twenty miles away. These apples were more ripe. Most of the larvæ in them were quite small, but a few were developing to larger size. Each lot was packed in a separate box and placed November 16 in a refrigerator maintained at an average temperature of 45 degrees. The apples were examined January 15. Of the non-infested fruit 50 apples were sound, 5 fair and 2 rotten; of the infested fruit 32 apples were fair to poor, 13 were rotten. Rotten apples were removed and the fruit replaced in the refrigerator. It was again examined February

14. Of the non-infested fruit 27 apples were fair to sound, 11 were decaying; of the infested fruit 8 apples were fair to poor, 12 were rotten.

NATURAL ENEMIES.

A ground beetle, *Agonoderus pallipes* Fab., was found in considerable numbers in the course of one field experiment. They were in the soil beneath a field cage. A number of pupæ of the maggot had been buried in this soil.

The beetles were suspected of interfering with the experiment. A few of them were placed in a lamp chimney with soil containing pupæ. Later some of these pupæ were found partly eaten. Additional beetles and pupæ were placed in the chimney, with similar results.

On other occasions scattering specimens of the same species were found in soil beneath infested trees, as would be expected, since the beetles are common. They were never observed actually at work destroying pupæ.

On several occasions where pupæ were kept in soil in pots or other containers some of them were found with a small, round hole in one side, somewhat toward one end. The source of this was not determined.

RECOMMENDATIONS.

In control of the Apple Maggot attention should be directed especially toward infested early varieties of apples.

The life economy of the maggot is essentially adapted to early types of fruit. The larva requires a mellowing pulp to reach maturity. This is readily available in the drops of soft, summer varieties. Winter fruit, especially of the hard, late-maturing type, is not adapted to the needs of the maggot. Midsummer drops of such fruit are likely to mellow sufficiently for the purposes of the larva, but in general few of the maggots that may be in winter fruit are likely to reach maturity. Infestation of such fruit is often due to flies derived from neglected earlier varieties near by.

In any fruit the very early drops, falling in June, offer no danger. Drops that fall after the end of September are not apt to mellow sufficiently for the maturity of the larvæ. The criti-

cal time is limited to the two-months period, from mid-July to mid-September.

The essential point of control is to prevent infested fruit from decaying on the ground. This is the one most important step, and is an efficient check. It is the only known measure that in itself is definitely effective.

This end may be accomplished by picking infested fruit before it ripens sufficiently to fall, by collecting drops by hand, or by making use of live stock to gather up drops.

The frequency with which drops should be collected depends on the variety of apple. With the earliest and softest of summer fruit, drops should be collected twice a week. This applies to apples of the type of Early Harvest. With early varieties of somewhat firmer flesh, such as Red Astrachan or Sops-of-Wine, once a week is sufficient. This applies also to the softer fall apples, such as the Porter. Later varieties may safely be collected once in two weeks, or longer with hard, winter fruit. With this schedule very few maggots in the apples will be able to leave the fruit and enter the soil for pupation. A reasonable rule to follow, whatever the variety, is not to permit infested apples to grow mellow or soft on the ground.

Drops that have been collected by hand, if not available for sale, may be disposed of by feeding to live stock, provided only as many are fed as the stock will eat. Otherwise drops may be placed in tight boxes or barrels. The refuse from these, after drying out, may be burned in a fire; or it may remain, and the following season the open ends of the containers may be covered with cloth or screen. In the latter case the remaining rubbish should be burned, since there may be live pupæ in it.

In making use of live stock the principle is the same as in the collection of drops by hand. The stock must be able to get at all drops, and must dispose of the same so that no fallen apples are permitted to decay on the ground. Hogs, cattle, sheep and colts are successful agents, but hogs sometimes injure trees. Hens are effective, if confined to a limited area, at the rate of 500 to an acre. Their value lies partly in their ability to find pupæ in the soil.

Whatever measures are adopted, full benefit is not likely to result the first following season, since live pupæ, representing

the two-year life cycle, may be in the soil, derived from the previous year's neglected drops. This may not, however, apply to the use of poultry, because the latter, if confined in sufficiently limited space, may find and destroy the pupæ in the ground.

Any apple trees worth the space they occupy should be sprayed. The ordinary spraying for codling-moth and for apple diseases is of indirect help in efforts toward control of the maggot because such spraying tends to reduce dropping of the fruit.

Wild apple trees in the vicinity of the orchard should be grafted over to fruit of value or cut down. Usually they are infested with the maggot, as well as other apple pests, and their presence is a source of constant danger.

The possible complication that may be offered by adjacent blueberries attacked by the apple maggot remains to be worked out. If such fruit is found infested close by, it should be removed and destroyed.

With the apple maggot as with other insects the practices of one's neighbors may help or may hinder efforts at control. However, the influence of neighboring places is less with this species than with many others because of the tendency of the flies to remain near the place where they emerged, so long as there are suitable apples in which they may lay their eggs. It is believed that the flies seldom travel in numbers a distance of 100 rods.

If winter fruit shows attack by the maggot on picking it should be disposed of promptly, or placed immediately in cold storage. Sent at once to cold storage it may be expected to keep fairly well. In no case should such apples be allowed to remain in the orchard or barn for a period after picking. Such practice is likely to result in rapid deterioration of the fruit.

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